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JANUARY 1960

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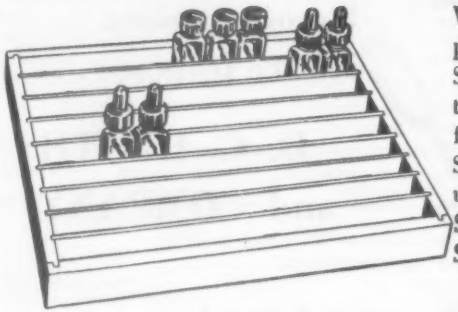

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CONTENTS FOR JANUARY, 1960

Konstantin Tsiolkovsky, Pioneer Astronaut—*Enoch J. Haga* 1

Smoke Doesn't Always Rise—*Glenn F. Powers* and *Faril Simpson* 4

The Unit Fractions of Ancient Egypt—*Walter H. Carnahan* 5

A Simplified Method for Determining the Approximate Relative Thermal Conductivity of Gases—*Aurlocolus C. Herald, Jr.* 10

Some Antics with Semantics—*Leonard H. Golber* 14

Look and See—*Arthur C. Murdock* 16

Particle Detectors Used in High-Energy Physics—*Edward C. Calhoon* and *Glen W. Watson* 17

A Question About Angle Bisectors—*A. R. Amir-Moéz* 25

181 Million Acres of Nature—*C. W. Mattison* 27

Means and Progressions—*H. D. Larsen* 34

Accuracy of Statement—*R. F. Graesser* 35

Evidence Evaluation—*B. Clifford Hendricks* 36

The Function of the Engineering Technician in Industry—*G. Ross Henninger* 41

The First Two Years of the Space Age—*Nathan L. Nichols* 57

Taking the School Out-of-Doors—*John W. Brainerd* 63

A Major Experiment for Teaching Meaningful Electricity Fundamentals—*R. E. Showers* 67

Evolution of Pi: An Essay in Mathematical Progress from the Great Pyramid to Eniac—*Panos D. Bardis* 73

Problem Department—*Margaret F. Willerding* 79

Books and Teaching Aids Received 82

Book Reviews 84

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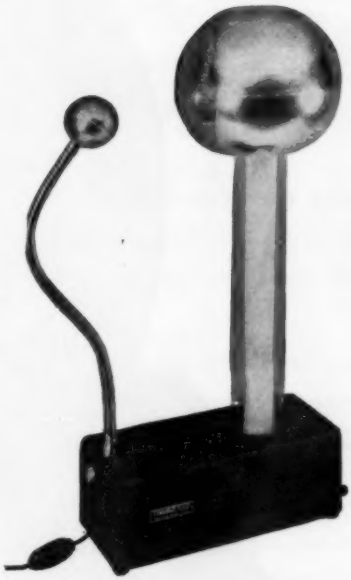

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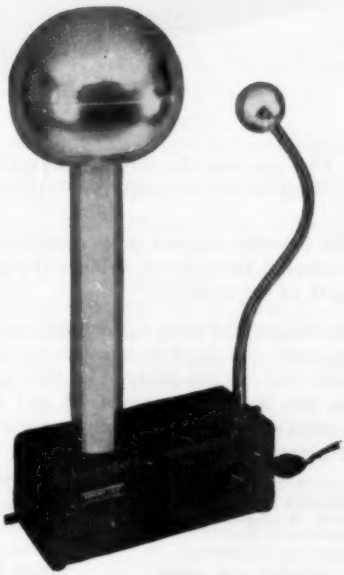

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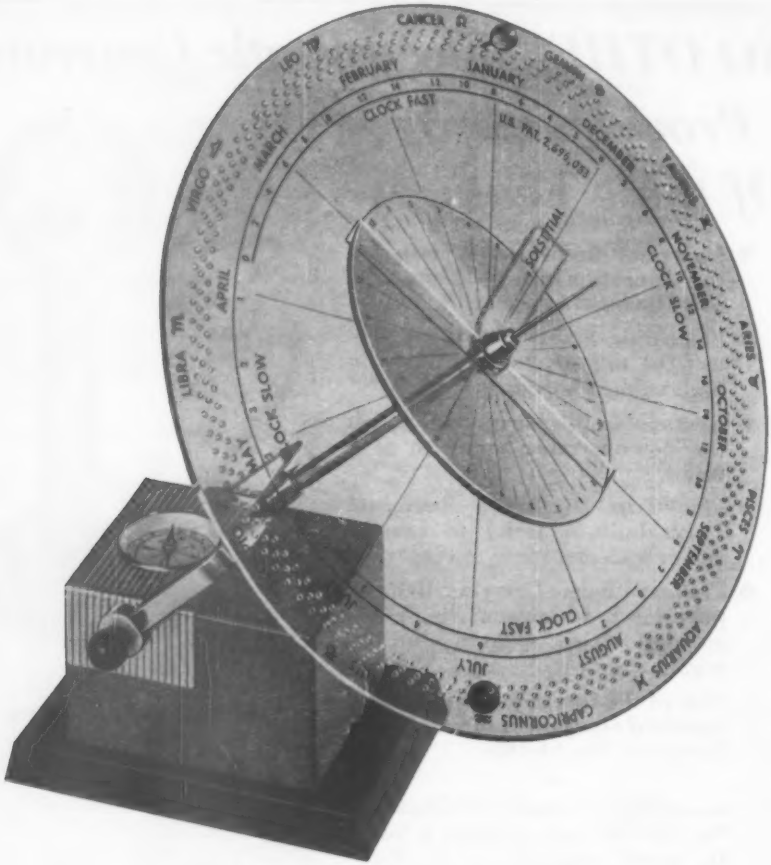

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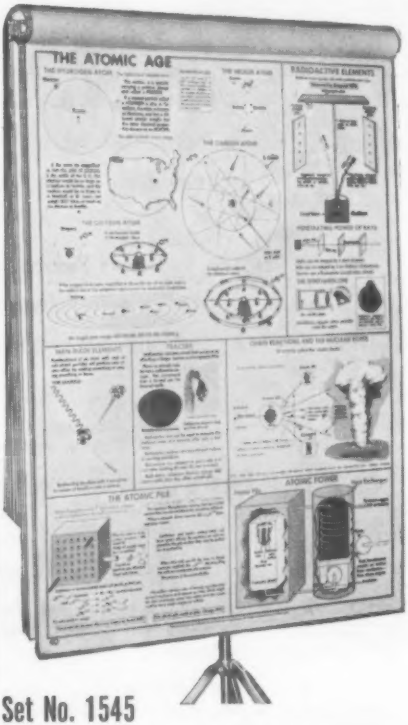

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Konstantin Tsiolkovsky, Pioneer Astronaut

Enoch J. Haga

High School Teacher, California Medical Facility, Vacaville, California

Of the many prophetic luminaries of space science and invention one is not so well known in America. He is Konstantin Tsiolkovsky (1857–1935), the Jules Verne of old Russia. From mathematics teacher to conqueror of space is the story of his life.

Forced to leave school at the age of ten because of severe loss of hearing caused by an illness, he continued studying at home. The boy later became a teacher of arithmetic and geometry in the district school. His teaching took most of his time, but what he had left he put to good use. Far ahead of his time, he designed the all-metal dirigible ten years before Count Zeppelin published his design; he designed the prototype of the all-metal airplane fifteen years before a similar ship actually was flown; but his work in rocket dynamics, jet propulsion, and artificial satellites is his crowning achievement.

Tsiolkovsky demonstrated the possibility of jet propelled flight in his book, *Free Space;* the year was 1883 and the world's first propeller driven planes were just then being perfected. He had as a youth studied, from a qualitative point of view, the principle of imparting or changing motion by thrusting back particles. It was twenty years later that he worked out his theory of jet propulsion.

Noting that the rubber-impregnated silk balloons of his day were not overly strong and that they quickly lost their hydrogen gas, he began working in 1885 on the design for his all-metal guided airship. But his most important contributions to aviation were perhaps his calculations and blueprints for a streamlined-metal bodied mono-

plane which incorporated a free supporting wing. Aerodynamically and in appearance, this plane was the forerunner of the type that flew fifteen years later.

Ten years later, in 1895, he wrote his *Dreams of the Earth and Sky*. Dreaming in terms of mathematics and physics, he gave birth to the idea for a permanently orbiting artificial earth satellite; he thought that such a satellite, used as a space station, would be useful in launching cosmic rocket ships.

Outlining the theory of rocket flight in his monumental work, *Exploration of Cosmic Space by Jet-Propelled Instruments*, 1903, Tsiolkovsky evolved the theory and presented his techniques for approaching the problem of interplanetary travel. At his home, Kaluga, now a national museum displaying skeletons of birds, photographs, the plane models he carved and the wind tunnel he made to test them in, one may still see the ancestor of Sputnik, the rocket model he built in 1903. Tsiolkovsky also thought-up the "jĕt train," really a multistage rocket.

He worked out what might be called an entire large-scale program for the research, development, and use of rocketry. Here is his plan:

1. Laboratory experiment.
2. Actual airfield testing of jet apparatus.
3. Low altitude flight and gliding descent.
4. Stratospheric penetration.
5. Extra-atmospheric flight and gliding descent.
6. Orbiting of artificial earth satellites.
7. Travel to the smallest bodies in the solar system.
8. Human colonization of the entire solar system.

He planned to make use of solar energy for nutrition, respiration, and also for transport and industry.

Always a dreamer, yet always practical, Tsiolkovsky carefully tempered his unusual theories, even those most bizarre, with careful practical considerations. He wrote: "I have worked out some aspects of the problem of rising into space by means of a jet appliance reminiscent of a rocket. Mathematical conclusions based on scientific data and verified many times indicate the possibility of rising into space by means of these appliances and possibly even of founding human settlements far beyond the limits of the terrestrial atmosphere."

What motivated Tsiolkovsky in his quest to send mankind into space? His work unrecognized and unrewarded until he was over sixty, he wrote early in this century: "The basic motive of my life is to do something useful for mankind. . . . That is why I was interested in what gave me neither bread nor strength. But I hope that my work will, perhaps soon, perhaps in the distant future, bring men mountains of bread and vast power."

After the October Revolution Tsiolkovsky received recognition and funds to carry on his work. His books received wide attention and engineers began to bring his dreams into the focus of reality. Speaking at the 1933 May Day celebration at the age of 76, he said: "The dream that I proved theoretically will come true. . . . It took me 40 years to develop the jet engine, and I had thought that a flight to Mars would be possible only after many more centuries of work. But time has shrunk."

Man is now timidly probing beyond the atmosphere. Later, Tsiolkovsky predicted, man will "gain for himself all the space around the sun." But, he thought, it would be a cooperative venture —the efforts of all mankind and all peoples would be necessary.

On October 4, 1957, just one hundred years after his birth, Sputnik vindicated the words carved on Tsiolkovsky's memorial shaft: "Mankind will not remain bound to the earth forever." A century of dreams had awakened to the touch of the scientists of the world. Konstantin Tsiolkovsky, space pioneer, helped point the way toward rocket flight into the cosmos. In his last years he expended furious energy on his plan for a space station; it was to be constructed of rockets whose fuel had been consumed in flight. He thought that solar energy would make it possible to grow food in the station for subsistence in space.

It is a fitting tribute to Tsiolkovsky that one of the craters on the hidden side of the moon, photographed by Lunik III on October 7, 1959, has been given his name.

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Smoke Doesn't Always Rise

Glenn F. Powers

Chairman, Department of Physics, Northeast Louisiana State College, Monroe, Louisiana

and

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This simple demonstration has evoked considerable class interest and discussion. A cigarette is lighted and held out for the class to observe. The smoke, of course, rises toward the ceiling.

Now the cigarette is thrust (burning end down) into an empty coke bottle held vertically, with open end up. Some of the smoke still rises, but soon dense clouds of smoke begin to *fall* down into the bottle.

The most common explanations elicited from general physics and general chemistry classes fall into two categories: physics students tend to "explain" the observed result on the basis of kinetic molecular theory and the expansion of the heated gases near the burning end of the cigarette. They think that the heat of the burning end is sufficient to cause the air in that region to move *away* from the fire (that is, downward) rapidly enough to convey the smoke particles in that direction.

Chemistry students think that the chemical process of combustion taking place within the bottle rapidly reduces the amount of oxygen within the confined space, causing a strong "downdraft" to enter the mouth of the bottle. This downdraft carries the smoke along with it toward the bottom of the bottle. Another popular "chemical" hypothesis was that the percentage of carbon dioxide in the bottle increased due to the decrease of oxygen from combustion. The carbon dioxide became the vehicle for carrying the smoke particles which then had a tendency to sink, because of the greater density of carbon dioxide than air.

After some discussion, the class can be asked to predict what might happen if the bottle were placed in a horizontal position before the cigarette is inserted. The "chemical" hypothesis will predict a somewhat different result from the "physics" hypothesis.

Further possibilities can be explored either actually, or in "thought" experiments. For example the cigarette could be first inserted in a tight-fitting hole in a cardboard baffle, which is then held against the mouth of the bottle. The baffle would eliminate the "downdrafts" between the cigarette and the periphery of the bottle orifice.

The Unit Fractions of Ancient Egypt

Walter H. Carnahan
Madison, Indiana

About 1650 B.C. an Egyptian scribe named Ahmes prepared a manuscript dealing with mathematics. It contains various practical problems of area, volume and other applications, and it contains a table of unit fractions needed in solving these and similar problems according to Egyptian practice. This manuscript is based upon one that was some two hundred years older. Ahmes specifically states his dependence on the older manuscript. Ahmes' manuscript, now known as the Rhind Papyrus, is still in existence. Engraved reproductions and translations are readily available.

One of the unusual features of arithmetic in Ancient Egypt as revealed in Ahmes' manuscript is the use of unit fractions, that is, fractions whose numerators are 1. The ancient Egyptians expended much labor in reducing every fraction to the equivalent sum of unit fractions and the results were carefully preserved and passed on to those who had to do computations. For example,

$$\frac{2}{5}=\frac{1}{3}+\frac{1}{15},\quad \frac{2}{7}=\frac{1}{4}+\frac{1}{28},\quad \frac{2}{99}=\frac{1}{66}+\frac{1}{198}.$$

Ahmes gives a table of unit fraction equivalents for fractions that have numerator $N=2$ and denominators D odd numbers from 3 to 101, that is,

$$\frac{N}{D}=\frac{2}{2n+1},\qquad n=1 \text{ to } n=50.$$

However, the writer refers to "2 divided by 5," for example, rather than to $\frac{2}{5}$. This table was useful in transforming certain fractions to unit fractions, the transformations required being those involved in solving the problems stated in the manuscript or similar ones. A little later we shall show how the table could be used in such transformations.

In writing a unit fraction the Egyptians used no bar to separate numerator and denominator or dividend and divisor. However, in such fractions they did write the numerator above the denominator, the relative positions of the two terms agreeing with those in our common fractions. In hieratic writing a dot replaced 1 as the numerator. Two fractions to be added were simply written side by side with no sign between as we write the sum of an integer and a fraction. Thus, for $\frac{1}{4}+\frac{1}{28}$ Ahmes writes $\dot{4}\ \dot{2}8$, using the Egyptian symbols for 4 and 8, of course. There were three exceptions to the general state-

ments here made; there were special symbols for $\frac{1}{2}$, $\frac{1}{3}$, and $\frac{2}{3}$, the last named fraction being the only non-unit fraction used.

One possible explanation of the use of unit fractions is that the Egyptians seem to have regarded each integer and its reciprocal as an associated pair. A tabular arrangment will emphasize this.

2	3	4	5	6	7	8	9	11	17
$\frac{1}{2}$	$\frac{1}{3}$	$\frac{1}{4}$	$\frac{1}{5}$	$\frac{1}{6}$	$\frac{1}{7}$	$\frac{1}{8}$	$\frac{1}{9}$	$\frac{1}{11}$	$\frac{1}{17}$

Still another explanation of the use of these fractions may relate to practical matters of partition such as distribution of loaves of bread among soldiers or division of fish among fishermen on a boat. For example, if there are two loaves of bread to be divided equally among five men, the person making the distribution might ask himself, "Have I enough for half a loaf to each man?" A quick calculation shows that the answer is "No." "Have I enough for one third of a loaf to each man? Yes, and one third of a loaf left over. Equal division of $\frac{1}{3}$ of a loaf among 5 men gives each $\frac{1}{15}$ of a loaf." Thus two loaves divided equally among 5 men gives each $\frac{1}{3}+\frac{1}{15}$ of a loaf. We modern people might think it would be simpler to do abstract arithmetic and decide to give each person $\frac{2}{5}$ of a loaf, but from the practical point of view of cutting bread there is something to be said in favor of unit fractions.

How the Egyptians made general transformations of fractions to unit fractions we do not know. It is probable that different scholars had different rules of operation, and perhaps the same scholar was not always consistent, that is, he did not use an unvarying rule or formula. The nearest that Ahmes comes to explaing how he derives unit fractions is in setting down a sequence of steps that enable him to find unit fractions. However, he sometimes follows one sequence of steps and sometimes another. He does not explain why he varies his sequence although in some cases the explanation is fairly obvious. In general, he seems to try to get simple combinations of unit fractions, and he prefers to operate with 2 and 3 rather than with larger numbers. We here give Ahmes' development for division of 2 by 5.

2 divided by 5

$\frac{1}{3}$ of 5 is $1\frac{2}{3}$ $\quad$ $\frac{1}{15}$ of 5 is $\frac{1}{3}$

Working out

1 $\quad$ 5

$$\frac{2}{3} \qquad 3\,\frac{1}{3}$$

$$\frac{1}{3} \qquad 1\,\frac{2}{3}$$

$$\frac{1}{15} \qquad \frac{1}{3}$$

Notice that in the part that Ahmes calls "Working out" there are four steps. We can interpret them thus: $1 \cdot \cdot \cdot 5$ means "All is 5." In the second step $\frac{2}{3} \cdot \cdot \cdot 3\frac{1}{3}$ means "$\frac{2}{3}$ of all is $3\frac{1}{3}$." The other steps can be similarly explained. As a final step Ahmes would observe that addition of $1\frac{2}{3}$ and $\frac{1}{3}$ in the last two lines gives 2, the number being divided. So he arrives at the unit fractions $\frac{1}{2}$ and $\frac{1}{15}$ as equivalent to 2 divided by 5.

For 2 divided by 13 Ahmes gives:

$\frac{1}{8}$ of 13 is $1\,\frac{1}{2}\,\frac{1}{8}$ $\quad$ $\frac{1}{52}$ of 13 is $\frac{1}{4}$ $\quad$ $\frac{1}{104}$ of 13 is $\frac{1}{8}$

$$1 \qquad 13$$

$$\frac{1}{2} \qquad 6\,\frac{1}{2}$$

$$\frac{1}{4} \qquad 3\,\frac{1}{4}$$

$$\frac{1}{8} \qquad 1\,\frac{1}{2}\,\frac{1}{8}$$

We can restate Ahmes' results as

$$\frac{2}{13} = \frac{1}{8} + \frac{1}{52} + \frac{1}{104}.$$

A simpler result would be

$$\frac{2}{13} = \frac{1}{7} + \frac{1}{91}$$

but Ahmes prefers dealing with reciprocals of powers of 2, no doubt because of the Egyptian practice of using binary numbers in multiplying and dividing. To understand why Ahmes did not start this particular development by taking $\frac{2}{3}$ of 13, then $\frac{1}{3}$ of 13, $\frac{1}{8}$ of 13, and so on, it is only necessary to try to get unit fractions by this approach. It is not easy. Perhaps Ahmes tried it and gave up, or perhaps the result was too complicated.

There is a very simple formula by means of which one can find the quotient of 2 divided by any odd number in terms of unit fractions. Suppose x and y are factors of $2n+1$. Then

$$\frac{2}{2n+1}=\frac{2}{xy}=\frac{2}{xy}\,\frac{(x+y)}{(x+y)}=\frac{2y+2x}{xy(x+y)}=\frac{2y}{xy(x+y)}+\frac{2x}{xy(x+y)}$$

$$=\frac{1}{x\left(\frac{x+y}{2}\right)}+\frac{1}{y\left(\frac{x+y}{2}\right)}.$$

Now, since $2n+1$ is an odd number, its factors x and y are both odd and their sum is an even number. Hence, $(x+y)/2$ is an integer. Therefore, the final expression in the above development gives two unit fractions. For example,

$$\frac{2}{29}=\frac{1}{1\left(\frac{29+1}{2}\right)}+\frac{1}{29\left(\frac{29+1}{2}\right)}=\frac{1}{15}+\frac{1}{435}.$$

Even without the formula, one can write

$$\frac{2\times 15}{29\times 15}=\frac{29+1}{435}=\frac{1}{15}+\frac{1}{435}$$

but 15 has 3 and 5 as factors and the Egyptians would hardly have considered using them, or at least they would have avoided 5. Besides, the multiplication of numerator and denominator by a common factor as an approach to a solution seems not to have been used by them. As another comparison consider that our formula gives readily

$$\frac{2}{83}=\frac{1}{42}+\frac{1}{3486}$$

whereas Ahmes gives

$$\frac{1}{60}+\frac{1}{332}+\frac{1}{415}+\frac{1}{498}.$$

We have said that the Egyptians computed a table of fractions with numerator 2 and used this in making computations where a fraction has numerator other than 2. We shall give an example to show how this can be done. Suppose we wish to transform $\frac{5}{13}$ to unit fractions by using the table. The steps would be as follows.

$$\frac{5}{13}=\frac{2}{13}+\frac{2}{13}+\frac{1}{13}=\left(\frac{1}{8}+\frac{1}{52}+\frac{1}{104}\right)+\left(\frac{1}{8}+\frac{1}{52}+\frac{1}{104}\right)+\frac{1}{13}$$

$$=\left(\frac{1}{8}+\frac{1}{8}\right)+\left(\frac{1}{52}+\frac{1}{52}\right)+\left(\frac{1}{104}+\frac{1}{104}\right)+\frac{1}{13}$$

$$=\frac{2}{8}+\frac{2}{52}+\frac{2}{104}+\frac{1}{13}=\frac{1}{4}+\frac{1}{26}+\frac{1}{52}+\frac{1}{13}.$$

The substitution for $\frac{2}{13}$ is taken from the table of Ahmes.

It may be of interest to consider general transformation of a given fraction to the equivalent sum of unit fractions without aid of a table and without limitation of the numerator N to 2 and of the denominator $D \leqq 101$. Suppose we are to transform $\frac{5}{211}$ to unit fractions. We can write

$$\frac{5}{211}=\frac{2}{211}+\frac{2}{211}+\frac{1}{211}$$

and apply the formula which we developed earlier.

$$\frac{2}{211}=\frac{1}{1\left(\frac{211+1}{2}\right)}+\frac{1}{211\left(\frac{211+1}{2}\right)}=\frac{1}{106}+\frac{1}{22,366}.$$

Then

$$\frac{5}{211}=2\left(\frac{1}{106}+\frac{1}{12,366}\right)+\frac{1}{211}=\frac{1}{53}+\frac{1}{11,183}+\frac{1}{211}.$$

Thus, fundamentally we use Ahmes' principle but extend his table to $\frac{2}{211}$. There are other ways of making the transformation, and, of course, there are other equivalent unit fractions.

As a more difficult general transformation consider $\frac{97}{99}$. We shall give the steps without discussion.

$$\frac{97}{99}=\frac{2\times 48+1}{99}=48\left(\frac{2}{99}\right)+\frac{1}{99}=48\left(\frac{1}{90}+\frac{1}{110}\right)+\frac{1}{99}=\frac{48}{90}+\frac{48}{110}+\frac{1}{99}$$

$$=\frac{45+3}{90}+\frac{22+11+10+5}{110}+\frac{1}{99}=\frac{1}{2}+\frac{1}{30}+\frac{1}{5}+\frac{1}{10}+\frac{1}{11}+\frac{1}{22}+\frac{1}{99}.$$

Otherwise,

$$\frac{97}{99}=\frac{2\times 97}{2\times 99}=\frac{99+66+22+6+1}{198}=\frac{1}{2}+\frac{1}{3}+\frac{1}{9}+\frac{1}{33}+\frac{1}{198}.$$

Although arithmetic has long given up the practice of using unit fractions, we are compelled to admire the ancient scholars who mastered and used them, especially since the Egyptians were the first people to treat fractions systematically and remove their general operations from the category of the impossible.

A Simplified Method for Determining the Approximate Relative Thermal Conductivity of Gases

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Introduction

The relative thermal conductivity of a gas is defined as the time rate of transfer by conduction of heat across unit area through unit thickness for unit difference in temperature. The same thing may be said in terms of the equation

$$k=\frac{C_v nr}{A}$$

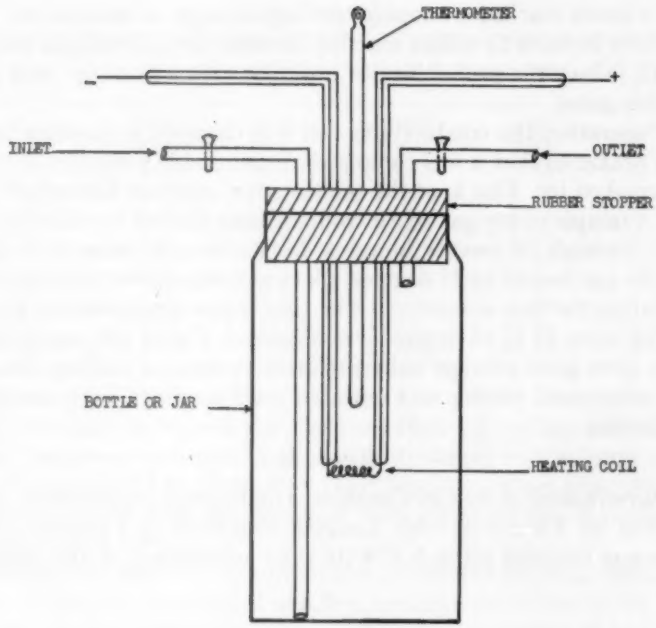
where k is the thermal conductivity expressed in calories per second per square centimeter, C_v is the molar heat capacity at constant volume of the gas in calories per mole per degree, n is the number of moles, r is the rate of cooling of the gas in degrees per second and A is the surface area of the experimental cell in square centimeters. The term relative thermal conductivity is used here because air was used as the standard for establishing the cell constant.

The most widely used method for determining thermal conductivity of gases is the "hot wire" method. In this method an electric current is used to heat a fine platinum wire in a cell kept at constant temperature by immersion in a thermostat. Different gases placed in the cell conduct heat at different rates. This means that in order to maintain the wire at the same temperature different amounts of electrical energy must be supplied. Hence the electric current used to maintain the wire at a definite temperature must be different for different gases. This method requires a rather elaborate experimental set-up. For student determinations or when only approximate values are needed, a simpler method would be useful.

The method described here differs from the above method in that measurements are made on the cooling rate of the gas rather than on the electrical energy used to heat it. The rate of cooling of a gas is related to its thermal conductivity (k), molar heat capacity (C_v), number of moles of the gas (n), and the surface area (A) of the experimental cell. Hence it is possible to calculate the thermal conductivity of a gas from measurement of its cooling rate in a cell of known volume and surface area using the equation given above.

Apparatus

The following materials and apparatus were used: a 2-liter beaker, 500 ml. gas collecting bottle, 18 gauge chromel wire, thermometer



(graduated to .01 deg.), two stopcocks, an electric timer, three $1\frac{1}{2}$ volt dry cells connected in series, gas drier, crushed ice, and samples of gases from cylinders of the usual type and purity supplied by commercial chemical companies (in this case 99.9% pure). Air was filtered and dried before use. Methane used in this investigation was the only gas below standard relative to state of purity. This was due to the use of natural gas for methane.

Procedure

The apparatus was assembled so that the gas collecting bottle was fitted with the thermometer, stopcocks, and heating coil made from chromel wire. This was conveniently done by using a large rubber stopper with five holes drilled as far apart as possible. The gas inlet extended to the bottom of the bottle while the outlet extended just below the lower surface of the stopper to provide efficient sweep-out. The heating coil was suspended near the lower third of the bottle with lead-ins sealed in glass to prevent leaks. It is important that the cell be made leak proof before being put into use. The number of dry cells required will depend upon the gauge of wire used to make the heating coil. The current in the coil was regulated so

that it never reached a temperature high enough to become red. This was done in order to reduce reaction between the coil and gas samples and to reduce the probability of explosion when working with combustible gases.

In operation the conductivity cell was clamped in position in the large beaker so that it was completely immersed in a mixture of water and crushed ice. This kept the temperature constant between 0° and 1°C. A sample of dry gas was introduced into the cell by allowing it to sweep through for twenty minutes. Both stopcocks were then closed and the gas heated to 25 degrees. (A switch was found convenient for regulating the flow of current.) The time interval required for the gas to drop from 20 to 15 degrees was observed. Use of this temperature range gave good average values relative to rates of cooling. Heating and subsequent timing was repeated until readings were consistent and precise.

Results

Determination of the Cell Constant. The thermal conductivity of air is given as 5.572×10^{-5} by Lange's *Handbook of Chemistry*. This value was rounded off to 5.57×10^{-5} and substituted in the equation

$$k=\frac{C_v nr}{A}.$$

The accurately measured volume of the cell was used to compute the number of moles of gas present (n), and the surface area of the cell was calculated from accurate measurement of its diameter and length. Solution of the equation for r gave a value of .2057 deg. per sec. The observed rate (r) was .0562 deg. per sec. Dividing the theoretical rate by the observed rate gave a value of 3.66 which was used in all subsequent calculations as the cell constant.

Conductivity Values for Eleven Gases. Data and computed values for rates of cooling (r) and thermal conductivity (k) for eleven gases have been summarized in the table below. For convenience, k is expressed as $k\times10^5$ cal. per sec. per cm^2.

Discussion of Results

It has been stated that the thermal conductivity of a gas may be expressed by the equation

$$k=\frac{C_v nr}{A}.$$

Values for k obtained by use of this equation were found to be in good agreement with those obtained from Lange's *Handbook of Chemistry* for the eleven gases shown in the table above. The cell constant,

TABLE I

Gas	C_v	t(cor)	r(deg/sec.)	k(×105)	k(accepted) (×10⁵)
Cl_2	6.14	89.7	.0557	1.82	1.83
H_2S	6.57	57.8	.0865	3.04	3.045
CO_2	6.92	54.5	.0916	3.38	3.39
C_2H_2	7.93	47.7	.1039	4.42	4.4
NH_3	6.57	34.2	.146	5.13	5.135
NO	5.11	32.8	.1522	4.16	4.16
CH_4	6.59	24.5	.204	7.16	7.2
Air	5.07	24.3	.2053	5.56	5.572
O_2	5.05	23.7	.2110	5.68	5.7
H_2	4.91	3.32	1.509	39.6	39.6
He	2.98	2.36	2.108	33.6	33.6

3.66, was used to correct the observed time for cooling over the selected temperature range. Cooling rate values (r) were average values for the range of 15 to 20 degrees. Heat capacity values were obtained by computation from specific heat data given by the *Handbook of Chemistry and Physics*.

Reasonably accurate determination of relative thermal conductivity of a gas may be made if one first assumes the value for air to be known and then carefully measures the rate of cooling of air in the cell.

CONCLUSIONS

1. The relative thermal conductivity of a gas may be determined by measuring its rate of cooling in a suitable cell of known volume and surface area.

2. The method of determining relative thermal conductivity described here was found suitable for student determinations or in general for obtaining good approximate values in a greatly simplified manner.

SAMPLE CALCULATIONS

Value of n, moles of gas in the cell:

Vol of cell = 510 ml

$$\text{moles} = n = \frac{510 \text{ ml}}{22414 \text{ ml}} = .0227$$

Surface Area of Conductivity Cell:

area of the bottom = $\pi r^2 = 3.1416 \times (3.55 \text{ cm})^2 = 39.6 \text{ cm}^2$

area of main body = $2\pi rh = 2 \times 3.1416 \times 3.55 \times 15 = 334 \text{ cm}^2$

area of neck = $2\pi rh = 2 \times 3.1416 \times 3.5 \times 2.35 = 51.6 \text{ cm}^2$

Total surface area = $39.6 + 334 + 51.6 = 425.2 \text{ cm}^2$ (425)

Thermal Conductivity of Carbon Dioxide:

observed cooling time = 14.9 secs.

corrected time = $3.66 \times 14.9 = 54.5$ secs

rate of cooling = $\frac{20° - 15°}{54.5 \text{ secs}} = .0915$ deg. per sec.

$$k = \frac{C_v nr}{A} = \frac{6.92 \times .0227 \times .0915}{425} = 3.38 \times 10^{-5}$$

Some Antics with Semantics

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The fact that a man is a mathematician does not necessarily free him from the wish to impress others. However, the gratification of this temptation has helped to disseminate a fallacy which is now so widely spread that it is in many books and has even appeared on television. It can be illustrated by the following dialogue, which adheres rather closely to the usual presentation:

Mathematician: Which is greater, the number of all numbers or the number of even numbers only?

Layman: The number of all numbers is twice-as-many as the number of even numbers only.

Mathematician: (triumphantly) No! The number of all numbers is *equal* to the number of even numbers, not twice-as-many, since they can be matched one-for-one. That is, for every number, odd or even, there is an even number which can be gotten by doubling the original number.

Layman: I don't follow you.

Mathematician: Imagine a theater. Every seat is occupied by one person and no one is standing. The number of persons and the number of seats may be matched, one-to-one. Therefore, without knowing how many there are of seats or persons, we still know that their numbers are equal. Now, returning to our mathematics, since we have an even number for every number, odd or even, that is, we can match *every* number with an even number, one-to-one, it follows that the number of even numbers equals the number of all numbers.

At this point Layman is supposed to slink away, crushed by Mathematicians clever presentation. However, let's assume that he is smarter than he usually looks and is not buffaloed so easily.

Layman: Returning to that theater—Assuming that each person in the audience is normal, can we conclude that the number of ears is twice the number of heads? We can match them two-to-one.

Mathematician: Yes.

Layman: Now for every even number there is itself and the odd number which can be obtained by subtracting one from the even number?

Mathematician: Yes.

Layman: Then every even number can be matched by two numbers. That is, it can be matched two-to-one.

Mathematician: Yes.

Layman: Then the number of all numbers *is* twice-as-many as the number of even numbers only.

Mathematician: But I have proven them equal by matching one-to-one.

Layman: And I have proven them twice-as-many by matching them two-to-one, an entirely analogous process.

The difficulty here is not one of mathematics but of semantics. It lies in the meaning of *equals* and of *twice-as-many*.

Mathematics has advanced greatly through the process known as as "formal extension." A law, or rule, is extended into a new field, one in which the rule may have no meaning or significance other than the formal way in which the symbols are manipulated. Later, at times much later, meanings are invented and uses found for what was previously merely a game. Thus, multiplication now includes the idea of rotation, as well as that of addition. Similarly, the number field has been extended from positive integers, to fractional and irrational numbers, to negative integers and to imaginary numbers. In making each extension we drop a limitation previously thought necessary and find that the law, as previously understood, was merely a special case of the law as newly extended. The invention of Quaternions, by Hamilton, is a beautiful example of this process. In this case the commutative law was abandoned.

Yet, the extension of a law does not invalidate its earlier and more naive applications. We still use multiplication to represent repeated addition, in appropriate cases. The broadened law, applied to the special case, should lead to exactly the same results as the unextended law. That is, the expansion of a law should not *negate* the previous statements of the law, it should *include* them. Thus, if we are going to extend the meaning of *equals* and of *twice-as-many* from the field of finite arrays to the field of infinite arrays, we must so state our definitions that when used in the *old* context, as applied to finite arrays, the definitions shall have their old meanings. This should be done for reasons of economy, simplicity and honesty.

A finite array may be defined as *equal* to another finite array if the members of one array may be matched, completely and regularly, one-to-one with the members of the other array, and can be matched *only* one-to-one. For infinite arrays we drop the limitation, "only."

It is obvious that we can, with as much validity, similarly define *twice-as-many*. A finite array has twice-as-many members as has another array if the members of the first can be matched, completely and regularly, two-to-one. Again, for infinite arrays, we drop the limitation, "only."

Having dropped the requirement that *only* one-to-one matching is a requirement for equality there is no reason for excluding two-to-one matching.

Subjectively, I feel that the number of ears is more appropriately described as twice the number of heads with which they are associated than as equal to them, even in an infinite array of eared heads.

There are those who will boggle at accepting an array as equal to another and simultaneously twice-as-many. For these persons I suggest the term *is matchable* be substituted for the word *equals* when referring to infinite arrays. This has the advantage of conveying the desired meaning without incrustations and would avoid quibbling.

At any rate—Layman was right!

Look and See

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Detailed drawings of various specimens are important in the study of biology. because they allow the student to observe closely and record what he sees. The old adage, "many look, but few see" is all too true. Therefore most of us must be taught to observe intelligently. This is one of the main arguments for including detailed drawings of plants and animals in a biology course. Most people believe that by drawing a flower or a crayfish the student will see more than he has ever seen before. Certainly the specimen must be seen before it can be drawn accurately on the paper.

In preparation for exercises such as those described above I have found it worthwhile to motivate the students by showing them how little most of us really see. The procedure is short and simple, taking only about ten minutes. It consists of asking the class members if everyone has seen for example a grasshopper. When you have all agreed on one common animal with which everyone is familiar, paper is passed out and the students are asked to draw one. They are then told to make a drawing detailed enough so that a person that has never seen a grasshopper will have no difficulty in recognizing one when the opportunity arises.

At this point someone in the class will probably comment that he cannot draw and never could. Invite this and similar students to describe in words what a grasshopper looks like. Point out however that the description must be sufficiently complete so that a person who has never seen one will recognize what one looks like from their description. Generally the individual will agree that even if his drawing ability is limited, he nevertheless can better describe one by a simple drawing than by words alone.

In about five minutes after the drawings are completed, they are collected. Then without revealing the names of the students discuss each description with pertinent comments. Some of the drawings will show four legs, others eight, some ears, others horns. At this point you are ready to pass out a preserved grasshopper to each student and have them observe for detail!

Particle Detectors Used in High-Energy Physics[1]

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Experiments in high-energy physics are directed toward discovering the origin of the intense but short-range force that binds the nucleus together. The method most widely used in this study is to bombard the nucleus with particles having sufficient energy to split it into its elemntary parts. Many of the new particles created in these collisions are unstable and decay into other types of particles within a billionth of a second or less. For an experiment to be meaningful, the physicist must be able to measure such things as the energy, electric charge, and mass of the particles involved, as well as the forces existing between the particles. To do these things requires highly specialized detecting equipment.

We may speak of particle detectors as belonging to two classes—the counters and the visual detectors. The counters count the number of charged particles passing theough their sensitive element, whereas the visual detectors give a picture of the tracks formed by the particles. The two types of counters which are employed in high-energy physics are the scintillation counter and the Cherenkov counter.

Because the scintillation counter is the more widely used of the two, we will describe it in some detail.

A scintillation counter consists of two basic parts: a material which emits a flash of light (scintillation) when a charged particle passes through it, and a device for observing this scintillation (Fig. 1). Some

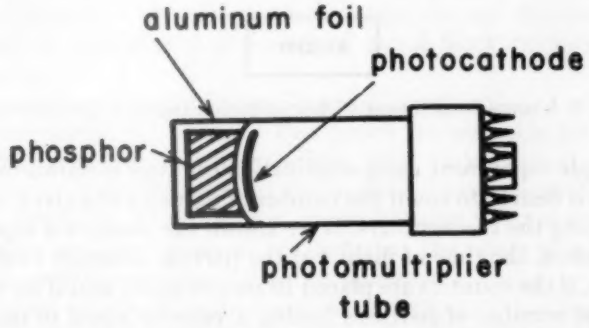


FIG. 1. One type of scintillation counter. A particle passing through the phosphor causes a flash, which is reflected by the foil onto the photocathode. Electrons are emitted which in turn strike successive stages of photocathodes so that an amplified electrical signal is produced at the output.

[1] Work done under the auspices of the U. S. Atomic Energy Commission.

of the more common scintillators (phosphors) are anthracene, an organic solid; argon, an inert gas; sodium iodide, in its crystalline form; and vinyltoluene, a plastic. Plastic scintillators are becoming more popular, since they can be easily formed into rings or other complex shapes.

Prior to the development of vacuum-tube circuits, the scintillations were observed visually. Unfortunately, the human eye is not sensitive enough nor the brain quick enough to catch all the faint flashes of light and to record the precise time at which each occurred. Imagine trying to count the number of sparks that fly off a grindstone and attempting to clock each one with a stopwatch. Yet nuclear particles are infinitely more elusive than sparks. Therefore, to observe the scintillations, we use a photomultiplier tube. When it sees a flash it sends an electric signal to an electronic device which counts the event. Perhaps an illustration will make this clearer.

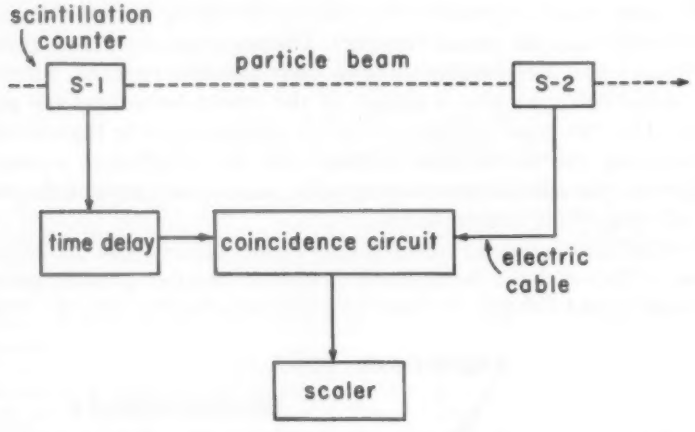


FIG. 2. A simple experiment with scintillation counters (S-1 and S-2).

A simple experiment using scintillation counters is shown in Fig. 2, where it is desired to count the number of particles of a given velocity v traversing the two counters. If we known the distance d separating the counters, the time of flight t of the particle is simply $t=d/v$. For instance, if the counters are placed 10 meters apart, and if we want to count the number of particles having a velocity equal to one-tenth the speed of light (3×10^7 meters/sec.), the time of flight is

$$t=\frac{10}{3\times10^7}$$

$$t=0.33\times10^{-6} \text{ second.}$$

What we must do then is set up the electronic apparatus so that it will record only those particles traversing the distance in this precise time. To do this we insert a time delay of 0.33×10^{-6} second in the electric line leading from counter S-1 to the coincidence circuit. The signals reaching the coincidence circuit will be in exact time coincidence for only those particles having the desired velocity. Whenever the coincidence circuit receives two simultaneous input signals it gives an output signal to the scaler, which counts the event. Usually, the scaler is set to count only a given percentage of the input pulses, say 10%.

A counting experiment utilizing the principle illustrated above was used in 1955 by Drs. Chamberlain, Segré, Wiegand, and Yipsilantis, of the Lawrence Radiation Laboratory, to discover the antiproton. In their experiment they set the time delay so that only those particles traveling a distance of 40 feet in the exact time of 51 billionths of a second would be recorded. Since none of the other negatively charged particles present could have that exact velocity, these signals could be caused only by antiprotons.

The scintillation counter is very useful because of its sensitivity, its extremely short time resolution (10^{-9} sec.), and its simplicity. But its spatial resolution of about 1 millimeter is so poor that it is worthless for measuring such things as the angle between the tracks of two particles produced in a collision or decay. To do this, we must use one of the visual detectors. This class of detectors includes the nuclear emulsion, the Wilson cloud chamber, the diffusion cloud chamber, and the bubble chamber.

The simplest of visual detectors is the nuclear emulsion. An emulsion stack consists of a number of layers of special photographic film called "pellicles." Charged particles passing through the stack expose the film so that when it is developed we see black tracks on a light background.

The nuclear emulsion has the best spatial resolution of any particle detector—about 0.1 micron.[2] This makes it invaluable for studying particles having very short half-lives, since they leave short tracks. Also the nuclear emulsion has the highest "stopping power" of the visual detectors, but this is a mixed blessing. The events are so numerous and the tracks so crooked that the effect of a magnetic field on particle curvature cannot be measured.

A major drawback to the emulsion technique is that each pellicle has to be painstakingly examined by a highly trained microscopist, who carefully measures coordinate points and grain density along the particle tracks. Until recently, these data had to be manually

[2]A micron is a millionth of a meter.

entered into a log. Later a physicist would use this information to perform tedious and complex calculations. The schedule of a ten-man research team might have read something like this: one day to expose the emulsion stack; one year to measure the tracks and record the data; another year to perform the calculations and analyze the results. In the enormity of their task they might have been likened to the Norse god Thor, who was challenged by Utgard-loki to drain a hunting horn with three drafts. Unknown to Thor, the horn was connected to the sea, so that no matter how long or how hard he tried he was unable to empty it, though each time he drank the oceans ebbed.

A recent invention by a group of scientists and engineers under the leadership of Dr. Walter Barkas of the Lawrence Laboratory has improved this situation remarkably. With the digitized microscope which they developed, an operator needs only align the cross hairs of the microscope on the particle track and then push a button (see Fig. 3). The three coordinates of the point under the crosshairs are automatically recorded on an IBM card. This process must be repeated for each coordinate point taken, so it is still a time consuming

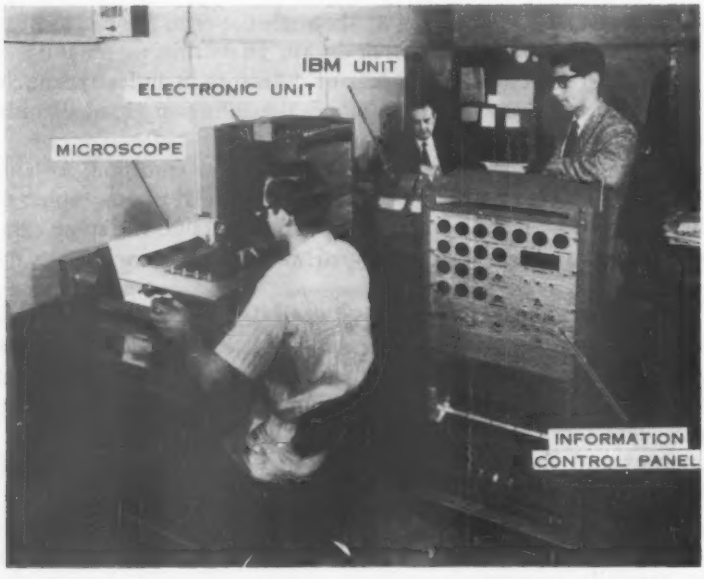


FIG. 3. Semiautomatic microscope used in scanning nuclear emulsions. Its inventors are Conrad Mason (left), Dr. Walter Barkas (center), Thomas Taussig (right), and James Hodges (not shown).

task. Even so, the taking of data has been speeded up by a factor of about eight over the earlier manual methods. The great advantage of this system is that once the data are on IBM cards, a digital computer can quickly and reliably perform the involved calculations.

The Wilson cloud chamber does not possess the limitations of the nuclear emulsion, but it has others of its own. A cloud chamber consists of a vessel containing moist air or gas in a supersaturated condition. A charged particle passing through the chamber leaves a visible trail of liquid droplets which can be readily photographed. Placing the chamber in a magnetic field causes the charged particles to curve in flight. The direction of curvature tells us whether the particle carries a positive or negative charge; the amount of curvature depends on the magnitude of the charge and on the momentum of the particle. Accurate calculations of the energy absorbed or released in a reaction can be made based on the momentum measurements.

Unfortunately, the cloud chamber has several inherent disadvantages. A beam pulse is available from a particle accelerator like the

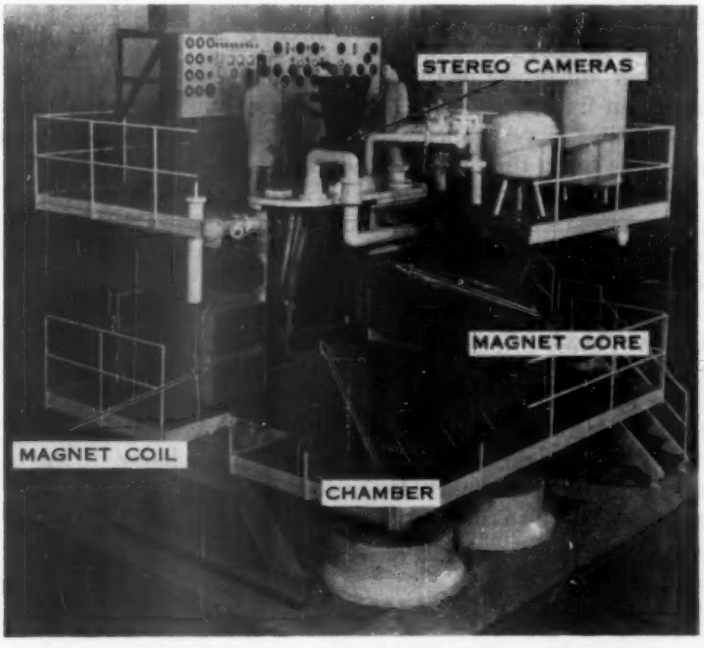


FIG. 4. Model of the 72-inch liquid hydrogen bubble chamber recently completed at the Lawrence Radiation Laboratory.

Bevatron every 6 seconds, but a cloud chamber has a dead time of a minute or two. Also, only a small percentage of the photographs contain interesting events. This is because the gas in a cloud chamber is not very dense, and relatively few bombarding particles strike a target nucleus. For these reasons, a cloud chamber is inefficient in utilizing the available beam, which is produced at considerable expense.

In an attempt to overcome these difficulties, the diffusion cloud chamber was developed, in which the gas is put under a pressure of 30 to 40 atmospheres to increase its density. This device is continuously sensitive but only in a very shallow area. The many reactions that occur either above or below this region are invisible.

A device embodying most of the merits of the visual detectors mentioned so far without retaining their principal disadvantages is the bubble chamber, invented in 1952 by Dr. Donald Glaser of the University of Michigan. Instead of a gas, a bubble chamber uses a liquid as its sensitive medium. Because of its much greater density, a liquid can be operated at relatively low pressures and still have very good stopping power for the incoming particles. Yet the stopping power is not so great that confusing tracks are produced, as is sometimes the case with the nuclear emulsion.

Another advantage of the bubble chamber is that it is sensitive throughout its entire volume, which may be quite large.[3] Moreover, its dead time is very brief—a photograph can be taken every few seconds. It has a time resolution of several microseconds, not quick enough for determining particle velocity, but adequate for distinguishing separate events. And finally, if liquid hydrogen is used then we have an ideal target, since there is no ambiguity as to what the struck nucleus is.

It was with a liquid hydrogen bubble chamber that a group of physicists, headed by Dr. Luis Alvarez of the Lawrence Laboratory, recently discovered the last of the elementary particles of ordinary matter which have been predicted to date. This is the xi zero, or neutral cascade hyperon—a particle about 25% heavier than a proton. Because the xi zero carries no electric charge, it leaves no track in a bubble chamber. Its existence must be inferred from the tracks leading up to the point where it was created and those following its decay.

A stereoscopic camera is used when taking bubble chamber photographs, in order to obtain a three-dimensional effect (see Fig. 5). If

[3] A bubble chamber containing 520 liters of liquid hydrogen was successfully operated in March at the Lawrence Radiation Laboratory (see Fig. 4). Several other large bubble chambers are now under construction at other research centers throughout the world.

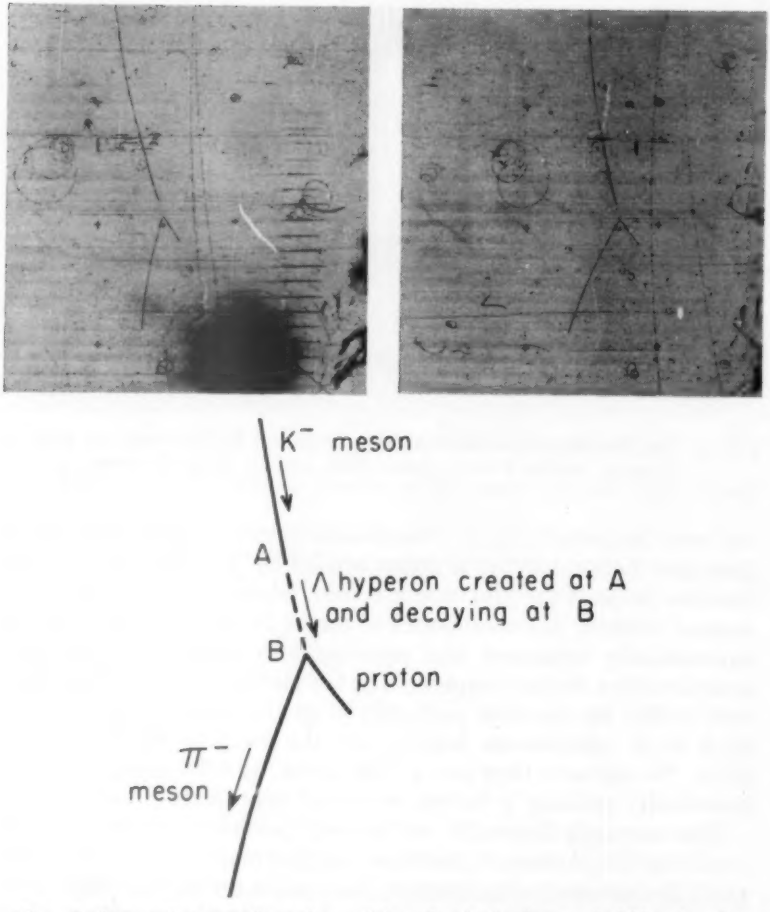


FIG. 5. Stereophotographs taken with a liquid hydrogen bubble chamber, showing an interaction between a K^- meson and a proton. The collision results in a lambda hyperon (Λ), which decays into a π^- meson and a proton. Since the lambda hyperon carries no charge, it leaves no track. The spiral tracks to the right and left are those of electrons.

this were not done, the path of the particle in real space could not be reconstructed mathematically and no usable information would be obtained. Therefore, it is necessary to measure the two-dimensional coordinates of points along the tracks in each stereo view. This is a very tedious job when done with a conventional measuring microscope.

To facilitate the taking of data, a device called "Franckenstein"

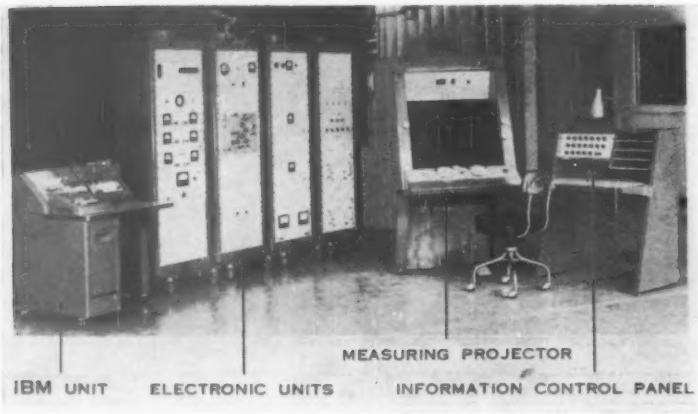


FIG. 6. The Franckenstein film-measuring projector. Its inventors are Jack V. Franck, Jerome Russell, Edson Skiff, and Dr. Hugh Bradner.

has been developed (Fig. 6). Franckenstein was designed and built at Lawrence Laboratory by a group headed by Jack V. Franck. This machine projects the film onto a screen, where, with a minimum of manual control, the coordinates of tracks in each stereo view are automatically measured and punched into IBM cards for later analysis with a digital computer. The fascinating feature of Franckenstein is that the operator need only align the optical index with the track in an approximate fashion, and the machine will lock on the track. The operator then uses a "foot pedal" to drive along the track, periodically pushing a button to record coordinate information.

This seemingly impossible feat is made possible by a scanning unit, consisting of a photomultiplier tube and electronic time discriminator, which feeds correction information back to the servomotors that drive the film carriage. This process is analogous to the operation of an automatic pilot which keeps an airliner flying on the beam.

With Franckenstein, all the necessary data from a pair of stereophotographs can be measured and recorded on IBM cards in from 5 to 10 minutes, on the average. With the earlier methods more than an hour was required for these steps, and then the information was often inaccurate owing to human errors. Franckenstein can measure a coordinate point of a particle track to an accuracy of 1 ten-thousandth of an inch (on the film), and it makes no mistake.

Equipped with a "drinking device" as marvelous as this, the god Thor might even have succeeded in draining the oceans, and thus have won his wager with the capricious giant, Utgard-loki.

A Question about Angle Bisectors

A. R. Amir-Moéz

Queens College, New York

Since the following proposition is asked frequently we thought you might like to have it handy.

Proposition: A triangle for which two angle bisectors are equal is isosceles.

For geometric proofs see

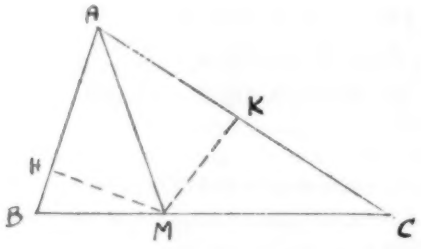
"Loomis, Original Investigation or How to Attack an Exercise in Geometry" republished by "The Bonded Scale and Machine Company, Columbus, Ohio."

An algebraic proof: In a triangle ABC for h_a, the altitude through A, we have

$$h_a^2=(a+b+c)(a+b-c)(a+c-b)(b+c-a)/4a^2$$

Let $AM=v=v_a$, the angle bisector of the angle A. Let $BM=x$ and $MC=y$. Then

$$x=ac/(b+c), \qquad y=ab/(b+c).$$



Let MH and MK be respectively perpendicular to AB and AC. Then MH is the altitude through M of the triangle MAB. Therefore

$$MH^2=(v+c+x)(v+c-x)(v+x-c)(x+c-v)/4c^2.$$

This gives

$$\begin{aligned}-4c^2MH^2&=[v+(x+c)][v-(x+c)][v+(x-c)][v-(x-c)]\\&=[v^2-(x+c)^2][v^2-(x-c)^2].\end{aligned}$$

Simplifying we get

$$-4c^2MH^2=v^4-2(x^2+c^2)v^2+(x^4-2c^2x^2+c^4). \tag{1}$$

Similarly for MK we get

$$-4b^2MK^2=v^4-2(y^2+b^2)v^2+(y^4-2b^2y^2+b^4). \tag{2}$$

If we multiply both sides of (1) by b^2 and both sides of (2) by $-c^2$ and add, considering $MH=MK$, we get

$$(3)\qquad \begin{aligned} 0=&(b^2-c^2)v^4+2[c^2(y^2+b^2)-(b^2(x^2+c^2)]v^2\\ &+b^2(x^4-2c^2x^2+c^4)-c^2(y^4-2b^2y^2+b^4), \end{aligned}$$

or

$$(b^2-c^2)v^4+2(c^2y^2-b^2x^2)v^2+b^2(x^4-2c^2x^2+c^4)-c^2(y^4-2b^2y^2+b^4)=0.$$

Now we see that

$$b^2x^2-c^2y^2=[a^2b^2c^2/(b+c)^2]-[a^2b^2c^2/(b+c)^2]=0.$$

Also

$$\begin{aligned} &b^2(x^4-2c^2x^2+c^4)-c^2(y^4-2b^2y^2+b^4)\\ &\quad=b^2[a^4c^4/(b+c)^4-2a^2c^4/(b+c)^2+c^4]\\ &\quad\quad-c^2[a^4b^4/(b+c)^4-2a^2b^4/(b+c)^2+b^4]\\ &\quad=a^4b^2c^2(c^2-b^2)/(b+c)^4+2a^2b^2c^2(b^2-c^2)/(b+c)^2+b^2c^2(c^2-b^2). \end{aligned}$$

Since in general $b\neq c$, (3) can be written as

$$\begin{aligned} &v^4-a^4b^2c^2/(b+c)^4+2a^2b^2c^2/(b+c)^2-b^2c^2=0, \text{ or}\\ &\quad v^4=b^2c^2[1+a^4/(b+c)^4-2a^2/(b+c)^2\cdot\\ &\quad v^4=[b^2c^2/(b+c)^4][a^2-(b+c)^2]^2. \end{aligned}$$

Therefore

$$\begin{aligned} v_a^2&=bc[a^2-(b+c)^2]/(b+c)^2;\\ v_b^2&=ca[b^2-(c+a)^2]/(c+a)^2;\\ v_c^2&=ab[c^2-(a+b)^2]/(a+b)^2. \end{aligned}$$

Now if $v_b=v_c$, then

$$ca[b^2-(c+a)^2]/(c+a)^2=ab[c^2-(a+b)^2]/(a+b)^2.$$

This can be simplified to

$$\begin{aligned} &cb^2/(c+a)^2-c=bc^2/(a+b)^2-b, \text{ or}\\ &bc[b/(c+a)^2-c/(a+b)^2]+b-c=0, \text{ or}\\ &bc[a^2(b-c)+2a(b^2-c^2)+b^3-c^3]/(c+a)^2(a+b)^2+(b-c)=0;\\ &(b-c)\{[bc/(c+a)^2(a+b)^2][a^2+2a(b+c)+(b^2+bc+c^2)]+1\}=0. \end{aligned}$$

Since the interior of braces is positive, we have

$$b-c=0, \quad \text{or} \quad b=c.$$

181 Million Acres of Nature*

(Better Interpretation of Nature on the National Forests)

C. W. Mattison

U. S. Forest Service, Washington, D. C.

Last summer I went back to a favorite place of mine on one of the National Forests—a place I have often visited. I was alone and sat at the very spot where I had sat so many times before. It was a good place to do some thinking.

I could see tree stumps, some freshly cut, others pretty well decayed. But as I looked upward, I could get only an occasional glimpse of white clouds against the sky. The rays of the setting sun, almost parallel to the ground, reddened an occasional tree trunk. There was a good forest still around and above me, evidence of good forestry practices on this land.

Beside me ran a stream of cold, clear water hustling around the rocks and over a tree trunk felled by nature many years ago. I had caught trout under those same rocks. That stream looked unchanged, proof that in using this forest, the forest rangers were carefully protecting its water values.

I was alone, but not unseen. As evening approached, I could hear sounds of forest wildlife as it scurried from place to place, completely out of human sight. Although I didn't know what animals were abroad, I did know there were bound to be several kinds of wildlife in this forest. Food, shelter, and water were plentiful for animals and birds. Wildlife needs were coordinated with other uses of the land.

Further down the stream was a little area with a few tables and fireplaces, refuse cans, two or three tent sites, a toilet, and ice cold water piped from a hillside spring. When I had walked through it, I could tell that a lot of people came there for picnics, camping and just plain relaxation and enjoyment. That little campsite was as clean as a whistle. Obviously, the users had good outdoor manners and "had left a clean camp."

All of these things were pretty obvious. Interpreting them was easy. Most of you, if you looked carefully, would interpret them just about as I did.

The National Forests are mightly big public properties. All together they make up that "181 Million Acres of Nature," the title of this talk. In interpreting that Nature, however, there's much more to consider than the obvious.

The user of National Forests—the camper, the hiker, the lumber-

* A talk before the American Nature Study Society and members of Science Teaching Societies affiliated with the American Association for the Advancement of Science, Washington, D. C., December 27, 1958.

man, the stockman, the fisherman, the hunter, the miner, the photographer, the picnicker, the skier, the loafer—is pretty much on his own when it comes to interpreting nature on these public forests.

These lands are unlike the National Parks where because of few entrances and more group opportunities, trained naturalists help the National Park visitor in his investigations of nature. Visitor centers and exhibits are key parts of the nature interpretive process. Nature interpretation for the visitor is a part of the program of the National Park Service, that group of dedicated people who administer your parks so well.

Right now is a good time to amplify the difference between National Forests and National Parks.

The 29 National Parks and some of the National Monuments were established to preserve permanently superlative examples of natural beauty for public use. Geologic features and all plant and animal life are carefully protected in them. By law they must be administered to provide for public enjoyment "in such manner and such means as will leave them unimpaired for the enjoyment of future generations." Thus, the parks are great outdoor museums and a significant part of our American heritage. The National Park System includes 177 different areas covering 23 million acres. The National Park Service is an agency within the U. S. Department of the Interior.

The 148 National Forests contain 181 million acres of public land. They are set up by law to yield products of use. They are administered in the public interest for the protection, development, and use of timber, water, range and other resources. National Forests are managed under the principle of multiple use. That means simply that most areas yield several different products or services at the same time. It does not mean that *every acre* will yield several products or uses. At some places, if one use is important enough, other uses may be excluded. The multiple-use plan provides for this. National Forests are administered by the Forest Service, an agency of the U. S. Department of Agriculture.

The National Parks are primarily areas to be seen and used for recreation, leaving the natural landscape as undisturbed as possible. While the National Forests are managed for the multiple use of their many values they also have a tremendous recreation value. There is more to a forest than meets the casual eye. And for one to fully appreciate a National Forest, or any forest for that matter, he should know something about forests and the role they play in nature's scheme. To put it another way, the forest visitor should do a little more than merely *see* the trees. He must observe closely. He can of course enjoy forests without close observation. However, if he brings this knowledge to bear in his observations, he will discern that besides

the beauty of a forest, it also works for us. So it is with the National Forests. Before interpreting nature itself on the National Forests, let's take a moment to study the key man in their administration and management—the forest ranger. His main job is to make his ranger district more productive and more useful to his fellow Americans. Sounds simple, doesn't it? But let's really analyze his job.

The ranger district is the key management unit of the National Forest System. If there is an "average" size ranger district, it is about 250,000 acres. Some are smaller, some larger, depending on topography, accessibility and workload. The ranger manages and develops this unit. Under national policies and regional and local guidelines he is responsible for everything that goes on in his district.

The ranger is responsible for the construction and maintenance of buildings, trails, fire towers, campgrounds, roads, and all the physical improvements needed in his district.

He battles insects and disease and fights fires. He surveys the timber resource, supervises the sale of timber, and wages war against litterbugs, timber thieves, and vandals of all kinds. He is concerned with increasing the watershed values and the timber and forage productivity of the land. In providing a good habitat for wildlife, he works closely with State wildlife people.

The ranger must do the land-use planning, determine the opportunities for multiple use of the land, be aware of the need for products and all uses of the lands in his care. If he possibly can, he must resolve conflicting interests right on the ground. His education and training fit him for the job.

The ranger is a professional man, trained at an accredited college of forestry or range management. He must have the character and leadership qualities required of all good business executives. Before he is promoted to ranger he usually has had several years of experience as an assistant ranger. The ranger has a big job, and he knows his business.

The ranger must be able to get along with people and to fit into the life of the community where he lives.

In all of his work, the ranger meets and works with people. He knows that people are more important than trees, and that his most responsible service is to people. The management and development of the forest in his charge, and all its resources, is but a means to serving the American people, as fully and efficiently as possible.

Now for some comments on the actual subject of this speech—better interpretation of nature on the National Forests. And again, let me say that you're pretty much on your own in making that interpretation. Rangers and other forest officers do conduct "show-me trips" when they can. There they interpret nature in its relation

to the *management* of the National Forests. However, for the average visitor—and "average visitors" paid about 61 million visits to the National Forests last year—nature interpretive service is not available.

All right. So you're on your own! You're going to do most of your own nature interpretation when you go to the National Forests. I can't help you very much in your interpretation of the millions of interesting and important natural details you will find. There are myriads of check lists, keys, books and similar aids to help you do that. Take them along.

I will talk, however, about some of nature's major phenomena on National Forests—some so gigantic that their significance is often completely lost to that average visitor.

What do you see in this picture other than beautiful mountains down below? What *did* you see in similar views as your plane winged its way toward Washington? What were the comments of your brother passengers as they oh'd and ah'd at the views? How did they interpret them?

Almost all of the land in this picture is National Forest land. Of course, not many plane passengers would recognize it as such. However, on most flights in the mountainous West, only occasionally is National Forest land out of sight if visibility is reasonably good.

Here is a little hint to help you identify those forests in flight. Take along ordinary road maps of the States over which you will fly. National Forests are shown on most of them by name and overall boundaries. Read these maps along with the airline route maps you find in your seat. If you are reasonably skilled in map reading, you will know when a National Forest is below. You will identify many of its natural features. With some study, you can interpret National Forest nature never even seen from the ground.

To return to the picture. The white stuff on that National Forest is more than snow. A rough estimate places the water content of that snow pack as great enough to supply the water needs of a large city for one full year. Did *you* interpret the snow in its relation to water supply?

Let's study the picture a little more. Look closely at the extreme top where the high snow-covered mountains fade into lower and almost snowless semi-desert. That in itself is one of nature's stories often misinterpreted. The mountains have intercepted the moisture as clouds carried it inland from the Pacific. That's a major reason for these mountains being part of the National Forest System—so that their water values can be protected in the public interest.

Take still another look. There are hundreds of watersheds down there. The little ones run in all directions, the big ones pretty much

north and south. All have the same function, to collect water from melting mountain snows and summer storms and funnel it slowly downward to the water users—the farmer and rancher, the householder, the recreationist, the manufacturer, the sportsman. This natural function is common to most National Forests from coast to coast. Did *you* interpret it properly?

For change of scenery, here's a ground look at one of the small reservoirs which store some of that water for municipal use. And now look at these high little National Forest lakes slowly yielding their snow water to the agricultural lands far below.

We're now on take-off for a sky view of a different kind of National Forest water—I call it recreation water. This is the Superior National Forest in Minnesota, one of the largest, and in my opinion, one of the most beautiful. It's a land of big and little lakes. All of you know of the Boundary Waters Canoe Area (formerly called Superior Roadless Areas) a part of this forest where aircraft are prohibited from flying at any altitude less than 4,000 feet. Under the National Forest management principle this area is dedicated to a special kind of multiple use—water recreation is so important that other uses are modified to affect it as little as possible.

Have you ever tried to interpret the National Forest timber resource, one of nature's bounties. It's more than just wood standing on the stump. First it's a protector of soil on the thousands of timbered watersheds across the Nation. It intercepts the sun's rays thus slowing down the spring run-off from melting snow. Sometimes it's so thick that thinning is necessary to get more snow to the ground. Snow retained on branches and limbs evaporates more quickly than that on the ground. Tree roots, like all plant roots, hold the soil in place and help water percolate into the ground.

National Forests furnish a part of our annual timber cut. About 12 per cent of the Nation's lumber comes from these public lands. The timber ready for harvest is sold on the stump under competitive bid to contractors who cut and remove it from the forest. In fiscal year 1958, 6.4 billion board feet of timber were cut on National Forests, bringing $86,275,000 in receipts to the National Treasury.

Under multiple-use, only a catastrophe will prevent the commercial forests on these lands from producing continuous yields of wood. The Forest Service is constantly trying to improve its efficiency in timber management as further assurance of continuous wood crops. This new type caliper only now coming into use, is just one small way to speed up the tree measuring process, a necessary part of timber management.

The Forest Service not only manages the trees that are growing with the idea of a continuous wood crop, but through research is

trying to find better species of trees and make other species grow faster. When you get a chance, visit one of the research centers on a National Forest. Take a little time to interpret some of the activities there. You can see the relation of certain hormones to tree growth. In test plots gibberellic acid applied to seedlings of eastern cottonwood, sycamore, yellow-popular, sweetgum, cherrybark oak, willow oak, and southern red oak increased growth from 75 to 350 per cent.

Closely related to the timber resource is wildlife. National Forests provide a habitat, or home, for one-third of the big-game animals in the United States—deer, elk, bear—and for birds and millions of small game animals and furbearers. About a fourth of all National Forest recreation visits are for hunting and fishing. Sixteen million such visits last year compared with 5 million in 1947—a 227 per cent increase in 10 years.

On National Forests wildlife needs—food, cover, and water—are provided for in managing and improving the timber resource. Any timber use involves the manipulation of the forest and, therefore, immediately affects the wildlife habitat. Observe it carefully sometime. The manner in which changes are made determines whether they will be helpful or harmful to wildlife. A variety of cover conditions creates desirable combinations of food and cover for most forms of wildlife. Therefore, clear cutting of small areas, or the selection cutting of groups of trees or single large trees, make openings in the forest. New growth in these openings is a good source of browse and herbaceous food, while the nearby forest provides escape cover. When you see timber harvesting on a National Forest, study it to make sure you interpret it properly in relation to wildlife needs.

Perhaps the things that are not done are of equal importance. Timber operators are not permitted to use stream channels in any logging opration. They are required to keep stream banks intact. They must construct culverts and bridges so that fish movement is not impeded. In a similar way, roads are located away from streams. Where roads must be built next to a stream channel, every care must be taken to maintain natural conditions. By advance planning, the resulting road system also serves as a means of access for hunters, fishermen, and other recreational users of the National Forests.

Fish and game must have a place to live. National Forests provide such a place. They yield a steady flow of clean water rich in fish life. They furnish food—berries for birds, browse for big game, seeds for small mammals. As more people seek outdoor recreation on these lands, the wildlife resource becomes more important.

Although it is only one of the major uses of National Forests, outdoor recreation is growing in importance every day. Americans are rediscovering their outdoor heritage. As the population zooms up-

ward and cities become more crowded, people are turning to woods, fields, and streams for relaxation and a sense of balance. This recreation pressure had been increasing on National Forests since 1945. It's not readily visible to you, but it is to the ranger. You may not interpret its impact on him and his staff, but let me tell you it is great. Last year 61 million visits were made to campgrounds, lakes and streams, picnic sites, and winter sports areas of these public lands. "Operation Outdoors," the Forest Service five-year program, is designed to take care of this growing recreation use now and in the years ahead—by cleaning up, expanding and rehabilitating existing areas, and building new ones. And for those who want their nature untouched, about 14 million acres have been set apart as wilderness.

All National Forest land is not forested. How many of you ever think of grazing, or forage—another major resource—in connection with National Forests? Some 4 million head of livestock—cattle and sheep—graze on these public lands for part of each year. National Forest range is mostly high country range, available only from three to five months each year, but just right to relieve the valley ranges on which ranchers run their stock in the spring and fall. About 20,000 ranchers use the forests for grazing under paid permits—another source of income, though modest, for the United States Treasury, and the States where the lands are located.

Before this land was put into National Forests, grazing was unrestricted and too often the lands were badly overused. Through improvements and careful management, the Forest Service has brought forage production and use more nearly into balance.

The snow that falls on the mountain ranges is as important as the forage because it is the water supply for the valley. Watershed protection, and management are kept in mind in managing grazing lands.

I have briefly discussed the five major resources of National Forests—water, timber, recreation, wildlife, and grazing. The casual visitor to these forests may never be aware of how these great natural resources are vital factors in his daily life—apart from the enjoyment he may get by looking at them or fishing, hunting, or picnicking in them. These resources are fundamental to the Nation's strength, and our economic well-being.

The great naturalist, Louis Agassiz once said, "Go to nature. Take the fact into your own hands. Look and see for yourself."

If you have not been, or have not been recently, I urge you to go to the National Forests and see for yourself. A day's travel time, from almost any place in the United States, will put you on a National Forest. And while you are there, by all means enjoy it—enjoy the incomparable beauty and the sense of contentment and peace which only nature's medicine can give. But also observe it—see beyond the

casual glance, the real and fundamental wealth which is there. If you do, you will come away with a new and different interpretation of nature, a new appreciation of all forests. You will have a new understanding of National Forests and the priceless heritage they are—to our country and to each of us as individuals.

Means and Progressions

H. D. Larsen

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In view of recent efforts in some quarters of introducing elementary statistical methods into the high-school mathematics curriculum, it might be of interest to note some relationships between the statistical means and the corresponding algebraical progressions.

THEOREM 1. The arithmetic mean of a set of variates in arithmetic progression is equal to the arithmetic mean of the first and last terms.

PROOF. Let the variates be a, $a+d$, $a+2d$, $\cdots$, l, where $l=a+(n-1)d$ and $S=\frac{1}{2}n(a+l)$. Since the arithmetic mean A of n variates is equal to their sum divided by their number, here

$$A=\frac{1}{n}\cdot S=\frac{1}{n}\cdot\frac{1}{2}\,n(a+l)=\frac{1}{2}\,(a+l).$$

Clearly, this is equal to the arithmetic mean of a and l as the theorem states.

THEOREM 2. The geometric mean of a set of variates in geometric progression is equal to the geometric mean of the first and last terms.

PROOF. Let the variates be a, ar, ar^2, $\cdots$, ar^{n-1}. The geometric mean G of n variates is equal to the nth root of their product. Thus,

$$\begin{aligned} G^n &= a\cdot ar\cdot ar^2\cdot\cdots ar^{n-1} \\ &= a^n\cdot r^{1+2+3+\cdots+(n-1)} \\ &= a^n\cdot r^{\frac{1}{2}n(n-1)}, \end{aligned}$$

whence

$$G=\sqrt[n]{a^n\cdot r^{\frac{1}{2}n(n-1)}}=ar^{\frac{1}{2}(n-1)}$$

But the geometric mean of the first and last terms is

$$G'=\sqrt{a\cdot ar^{n-1}}=ar^{\frac{1}{2}(n-1)}=G,$$

and the theorem is proved.

THEOREM 3. The harmonic mean of a set of variates in harmonic progression is equal to the harmonic mean of the first and last terms.

PROOF. Let the variates be $1/a$, $1/(a+d)$, $1/(a+2d)$, $\cdots$, $1/l$ where $l=a+(n-1)d$. The harmonic mean H of n variates is equal to the reciprocal of the arithmetic mean of the reciprocals of the variates. Here the reciprocals of the variates are a, $a+d$, $a+2d$, $\cdots$, l and their arithmetic mean (Theorem 1.) is $\frac{1}{2}(a+l)$. Consequently,

$$H=\frac{2}{a+l}\cdot$$

But one sees without difficulty that this also is the harmonic mean of $1/a$ and $1/l$, the first and last terms, respectively.

Accuracy of Statement

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Due to their training, mathematicians are habitually very careful to be exactly accurate in their statements. This is illustrated by the following anecdote.

When the Third International Mathematical Congress met in Heidelberg, Germany, in 1904, the firm of B. G. Teubner dedicated to the members of the congress an especially prepared, de luxe catalogue of their publications to which Professor Felix Mueller had contributed a list of "Memorable Dates for Mathematicians." Due to an error, such as may always occur, there appeared in this very worth while list, following the entry "September Fourth," the statement, "Richard Dedekind died 1899."

Under similar circumstances Mark Twain is supposed to have said, "The report of my death is greatly exaggerated." However, Dedekind, the great number theorist, who did not die until 1916, wrote the compiler of the list in the following vein:

"Respected Colleague: In your valuable 'Memorable Dates for Mathematicians' you have very kindly remembered me for which I thank you sincerely. Permit me, however, to call to your attention that, in the entry concerning my death, at least the year can not be correct."

WATER MUST BE PROTECTED FROM MINE CONTAMINATION

Water, our most essential natural resource, must be protected from acid pollution from abandoned mines.

Natural oxidation of the sulfuritic material associated with mining is the initial reaction responsible for this acidity.

Secondary reactions of the initially formed acid and acid salts with the earth and rock can produce mine discharges varying from high acid content to high alkali.

Evidence Evaluation

B. Clifford Hendricks

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Anton J. Carlson, Distinguished Professor Emeritus of Physiology of the University of Chicago, is dead. But his concern for valid evidence lives after him. "For over a half century he voiced protest over inadequate evidence of either the proponents of physiological outmoded theories or food and medical quacks in pure food litigation. His two questions, 'Vat iss the effidence?' and 'Vat are your controls?' were raised time and again in class rooms, laboratories and august assemblies, usually to the chagrin of the challenged individual."[1] Whether the challenged individual was chagrined or not probably depended upon the *use* to which "Ajax" (as Carlson was known by his students) made of that evidence.—Maybe *use* is one approach to its evaluation?

Kinds of Evidence

A St. Louis Post-Dispatch editorial, mid-March, 1958, ended with "The Vanguard, the Explorer, the Sputniks—all are soaring *evidence*, of the need for a race for peace." In early April of the same year suit was brought by a group of scientists and churchmen to halt United States bomb testing. This protest was, basically, that evidence for the harmlessness of "fall out" is inadequate.

From a meeting of the Parliament of Science (under the auspices of the AAAS) in Washington, March, 1958, came a report, "One result of recent applications of science has created hazards to human welfare which we are not able to understand. We are now handicapped by our ignorance of many biological questions which have taken on great urgency." The attendants at that "Parliament of Science" proposed that adequate evidence for better understanding be featured in future programs of research even to the point of restricting scientific endeavor that might, in a "spirit of adventure" become "heedless of consequences."

Courts of justice are permitted, even under dictators. Where there are courts there are witnesses whose services provide evidence. Presumably, the court evaluates that evidence.

In a recently published, *Philosophy of Religion*,[2] six of its twenty chapters are concerned with various aspects of evidence. Courts and

[1] *Tower Topics*, January, 1957, page 8. University of Chicago Press.
[2] D. Elton Trueblood, *Philosophy of Religion*, 1957, pages 90–161. Harpers.

laboratories are not the sole seekers of evidence. Others than "Ajax" are asking, "Vat iss the effidence?"

Evidence for What?

Faraday had just demonstrated that electricity may be generated by induction. The statesman, Gladstone, is reported to have asked, "What is it good for?" Faraday, after having identified his questioner, replied, "I think, Sir, you may be able to tax it some day." Rephrased that question was asking, "What is the purpose of your experiment?" With that purpose in mind an assessment (evaluation) of the observations (evidence) could be made with greater certainty. That is to say, evaluation evidence is guided by the use to be made of it after discovery. (That *does not mean* that only supporting evidence is to be recorded. Valid evaluation requires that every pertinent observation whether pro or con is to share in the final reckoning.)

Reckoning for Pertinence

Rules for evidence acceptability in the court room are probably older than any other code. When the attorney informs the judge, "I've got a witness," an experienced court reporter[3] retorts, "Good, but who's going to believe him?" There are a series of rules that help to answer that question. They include warnings about the use of relatives as witnesses; child witnesses or hearsay witnesses. They commend the assets of character witnesses; disinterested witnesses; expert witnesses and suggest ways for their most effective use if their testimony is to be fully credited. The legal profession has its pattern for evaluating evidence and courts of the land operate accordingly.

There is other than personal testimony that may claim court approval. Robert Ripley, of "Believe It or Not" repute, claims documentary proof for each of his stranger-than-fiction items. Since many of them are historical, proof would have to meet the demands of the historian. Their most acceptable evidence they label primary. That requires eye-witness testimony, either in person or by notorized affirmation. There is also what is known as documentary evidence. Tribute to that sort of evidence is implicit in documentary films. Photography is rated an instrument for recording such. Within the field of science great stress is placed upon objectivity as a criterion of valid evidence. Such evidence is expected to be reproducible. In the language of semantics it has a referent by use of which general agreement of all concerned may be attained. Carlson's demand for controls was his way of bringing referents into the evaluation of the evidence submitted.

Not all kinds of evidence may use referents, however. Strictly ap-

[3] Alexander Rose, *So You Are a Witness*, 1942, page 26. New York Institute Press.

plied, this tool-of-evaluation requires "observable, measurable or verifiable evidence." It is evident that there are "whole areas of experience such as ethical, the purely intellectual and the religious where its use would have no validity."[3a] So it appears that validity of evaluation involves proper concern as to the kind of evidence under scrutiny. This complicates the assessment but must not be ignored.

In the daily routine the need for evidence has to do with making choices. We want an answer to such questions as: "Shall I fly or take rail transportation since visibility is low?" Time saved pitted against safety. We use care in evaluating the evidence for and against for we do not want our choices to lead to disaster.

The Thews of Thought

"After all," says an interested listener, "whether it is a judge, or a jury or just plain John Doe, is it not just a matter of straight thinking?" The reply to that is, "Straight thinking , in turn, especially in science, involves not only reproducible evidence but a concern for the manner in which that evidence is used." Again we are faced by use as an aid to evaluation.

However, deciding to-use-or-not-to-use comes before use takes over. To guide in making that choice of pertinent evidence one author[4] proposes:

"1. Keep facts separate from opinions.
2. Check facts as to: what, when, where and who.
3. Get evidence from both sides.
4. Defer formulation of premature opinions.
5. Keep an open mind for more."

Another[5] who is concerned with more dependable thinking, which he calls "a new literacy for listeners," adds:

"1. Be sure words are distinguished from things for which they stand.
2. And that extrapolations are kept within the area of their factual basis."

Evidence as a Lure

The court reporter[3] says, "Proof is anything that will make some one believe you." A more acceptable wording would substitute "evidence" for "proof." Those bent upon the more critical evaluation of evidence may not even approve the revised statement. However, the reporter's quip may explain some of the tricks of the less scrupu-

[3a] D. Elton Trueblood, *ibid*, page 197.
[4] William J. Reilly, *Twelve Rules for Straight Thinking*, 1947, page 101.
[5] Stuart Chase, *Power of Words*, 1953, page 11. Harcourt Brace, & Company.

lous court room lawyers or some "ad-plugs" in TV commercials.

Screening evidence to delete the not-so-pertinent can be greatly aided by the use of catalogues of the "baits-for-the-gullibles." Nichols and Stevens[6] warn their listeners to beware of uncritical acceptance of:

1. Testimonials: Do prominent people know dependably about that which is not their specialty?
2. Card-stacking: Selected evidence for but one side of the matter. Not untruth but part truth.
3. Band-wagon appeal: This assumes the majority is always right.
4. Stereotypes: The false idea that *all* members of a group are the same as the few cited.
5. Name calling and prejudice appeals: Disgorged through emotionally charged words. An evening before the TV or a critical reading of many political speeches give abundant instances of these "lures to belief."

Subtle Subversion?

After an inventory of the extent of the before-mentioned practices one wonders:[7] "Is it possible that an excessive exposure to "merit by association," "brain-wash by repetition" and "jazzed doggerel" may lead to an *inability* to sense the irrational?" There is no doubt in the mind of Stuart Chase when he says,[7a] "(We are blanketing) the planet with words, thus compounding the perils of propaganda, half-truths and plain loud lies. We need a new literacy for listeners, to help them to distinguish between the real and the phoney, to help them identify motives, to know when to shut their ears, when to shut the—thing off."

Teacher Therapy

If Mr. Chase is right we as teachers should be concerned. But what can we do about it? Can we participate in achieving the "new literacy" said to be potent for this crying need? In previous articles[8,9] the science teacher has been credited with being uniquely privileged to help students practice the art of finding evidence in their laboratories. In assessing that evidence for making sound judgments they get first-hand exercise in evidence evaluation. In this, the laboratory, navigated by an understanding teacher, offers a sort of clinical service

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[6] Ralph G. Nichols and Leonard A. Stevens, *Are You Listening?* 1957, pages 134–137. McGraw-Hill Book Company

[7] B. Clifford Hendricks, "Communications Fall-Out," School Science and Mathematics, June, 1957, page 453.

[7a] Stuart Chase, *ibid.*, page 11.

[8] B. Clifford Hendricks, "Laboratory Evidence," *The Science Teacher*, September, 1953, pages 170–171.

[9] B. Clifford Hendricks, "Evidence Awareness," *The Science Teacher*, March, 1955, pages 78–80.

for developing awareness for objectivity. When that becomes a habit, evaluating evidence "operationally" is becoming dependable.

But, judging from the directions found in many of the laboratory manuals in current use, awareness of evidence as an outcome of laboratory work seems to be anything but explicit. If any such a service is rendered it seems to be reckoned as a sort of concomitant bonus that requires no especial attention. Of course, there is the possibility that the teacher may repair that oversight of the manual's author by her class room service. One wonders?

In the period around the 1930's there was an active interest in such matters as the nature of proof,[10] the "interpretation of data" and other aspects of evidence evaluation. Some of the subject matter tests[11] had sections on "interpreting experiments," "interpreting data" and there were calls for discriminating between evidence and theory in such interpretations. In the 1956 issue[12] of the American Chemical Society's examination in general chemistry there are a number of items calling for a distinction between "experimental evidence" and "theoretical explanations."

But is the insertion of probes for ability to make such a distinction to be the extent of our endeavor to critically evaluate evidence? Should there not be a planned program of attention to this phase of our science curriculum, antecedent to tests? In other words, if skill in the choice of the pertinent rather than the spurious evidence is to result from our school's work will it not be needful to plan and practice to that end?

Re-Evaluation

When concerned attention is given to the different sorts of evidence one finds its evaluation is not by any one simple recipe. We scientists, who are a bit elated over the help of referents, as a sort of an objective standard for evaluating evidence, need the admonition that "operationalism" may not be of universal validity for such purposes. The "high pressure" man of action, who drives for prompt returns, needs to be cautioned that his over-simplified code of evaluation maydo hurt to his patron even if it does make the more immediate sale. And even the teacher faces the temptation to settle with a program of drill since its outcomes are so much more tangible than are the evidences of personal maturation which her better judgment knows are to be striven for. In other words, do not these three groups (may be many others) need to re-evaluate their evaluations implicit in their practices?

[10] Harold Fawcett, *Nature of Proof* (Pamphlet), 1936. Ohio State University Press.

[11] Publications of Educational Testing Service, Princeton, New Jersey.

[12] A.C.S. *Cooperative Examination in General Chemistry, Form M*. 1956. Examinations Committee, St. Louis University, St. Louis, Missouri.

The Function of the Engineering Technician in Industry*

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The function—or place—of the Engineering Technician in industry is as broad and varied as the field of engineering itself. In fact, the place of the qualified technician is well established—and growing—across the whole spectrum of professional, technical, and business enterprise. It is neither new, nor peculiar to engineering, although engineering has been peculiarly slow in recognizing it.

I should like to develop my assigned topic through a discussion of what an engineering technician is and something of the philosophy involved in his development. First, let's look briefly at the "Technical-Institute Idea" in higher education. I cannot too strongly emphasize the critical necessity of approaching the whole idea of technical-institute education as a philosophy rather than as an institution.

The basic objective of the "Technical-Institute Idea" in higher education is the development of qualified Engineering Technicians proficient in a pre-selected field of technology. In general, the technical-institute program is designed to accomplish its objective within two academic years. Usually the Associate Degree is awarded for completion of such a program.

By way of emphasis, a contrast should be noted. The technical-institute program is not intended as a feeder channel to the university. The program is not the equivalent of the first two years of the university four-year engineering program—it is much more than that in some important respects, and somewhat less in others; its direction and emphasis are significantly different. In the sometimes confusing parlance of educators, the technical-institute program therefore is commonly referred to as a "terminal" program. This causes many qualified people to shy away from it, mistakenly. The technical-institute program is no more "terminal" than any other collegiate degree program. It is "terminal" only in that it is not specifically designed to meet the limiting requirements characteristic of most college and university catalogs for "transfer credits." The bona fide technical-institute program is designed instead to give the student a high degree of proficiency in a pre-selected field of technology, solidly supported by a sound working knowledge of the mathematics, English, basic science, and technological principles involved in that field.

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The philosophy of the "Technical Institute Idea" in higher education is that for every young person who has the capacity and incentive to pursue formal technological education through to the academic heights and professional frontiers represented by advanced collegiate degrees, there are many who have the capacity, interest, and aptitude to develop more productive and rewarding careers in the expanding realm of applied science and the technologies which neither require nor justify four or more years of collegiate study.

Definitions

For the purposes of the National Survey of Technical Institute Education, the following two definitions were developed. They became widely distributed during the course of the Survey in 1956–58 and have been adopted in whole or in substance by an increasing number of educational, industrial, and professional agencies.

The Engineering Technician.—In general, the engineering technician is a person whose chief interests and activities lie in the direction of the testing and development, the application, and the operation of engineering and scientific equipment and processes. Classified on the basis of educational certification, the engineering technician would be a graduate of a technical-institute type of curriculum as accredited by Engineers' Council for Professional Development, or recognized equivalent. Classified occupationally, the engineering technician performs semi-professional functions of an engineering or scientific nature, largely upon his own initiative and under only general supervision of a professional engineer or scientist; he assists, and supplements the work of, the engineer or scientist.

Typical among the wide array of semi-professional functions performed by engineering and scientific technicians are: Drafting, design, and development of products and of engineering plant; installing and operating equipment, estimating costs, selling, and advising customers on the use of engineering or scientific equipment.

In many instances, the technician may serve as a liaison between the engineer or scientist on the one hand, and the skilled craftsman or layman on the other hand. In carrying out these various activities, he may have group leadership responsibilities. Therefore, the technician must be able to communicate mathematically, scientifically, and linguistically.

Technical-Institute Education.—The term refers to the intermediate strata of technical curricula which are from one to three years' duration (full-time) beyond the high school level. Curricula are technological in nature, and they differ in both content and purpose from those of the vocational school on the one hand, and from those of the engineering college on the other hand.

Such curricula emphasize the understanding and practical application of basic principles of mathematics and science, rather than the acquisition of proficiency in manual skills. High school graduation is required for admission, and mathematics through algebra and geometry are prerequisite.

The programs of instruction are similar in nature to, but briefer and more completely technical in content than, professional engineering curricula. The major purpose is to prepare individuals for various technical positions or specialized areas of activity encompassed within the broad field of engineering enterprise.

Relationships in Educational Spectrum

In considering the proper place of the technical-institute program in the national educational and professional spectrum, attention must be focused upon the fact that it is the engineering field which has "exploded." As the results of scientific research complicate the tasks to be performed by the engineer—whether he be in development, production, or construction—and carry the field of the engineer further away from the realms of application and operation in which modern engineering started and has grown, two facts stand out with increasing clarity.

The first fact is that some adequate and integrated provision must be made to continue to supply the technically competent manpower required for this engineering application and operation, and required also to augment and to supplement the professional engineer and the scientist in research, design, development, and supervision. This manpower is a part of the over-all engineering manpower spectrum. In general effect, it is taking the place of "the engineer" as we have known him in the past, as "the engineer" of today and of tomorrow increasingly takes his new place and becomes more and more devoted to the scientific problems and opportunities of the expanding technological universe. This manpower area is the professional area of the "engineering technician."

The second fact is that, for his optimum development, the engineering technician is best served by an educational program which is intimately related to, but which differs significantly from, the program most effective for the engineer, and which likewise differs significantly from the educational program most effective in developing or enhancing the skills and the "know how" of the craftsman. In contrast to the engineer, the engineering technician does NOT need to have either the depth or the extent of mathematical or scientific understanding required by the engineer. However, the engineering technician DOES need to have a practical working understanding of essentially the same subject matter, together with appropriate communication skills and mathematical competence. To achieve the necessary results, this requires an educational approach comparable in quality and general level to the university-collegiate engineering program, but differing significantly in that the emphasis required is that of practical application of established scientific principles rather than the development of new design concepts or the extension of existing knowledge.

Further, in contrast to the craftsman and his appropriate educational program of vocational-trade skills and related subject matter, the engineering technician does NOT benefit significantly from the development of proficiency in manual or manipulative related skills

nor from technological subject matter taught from that angle. However, the engineering technician DOES need to have a general working knowledge and appreciation of the manufacturing or operational manual skills related to his area of occupational and subject-matter interest. For uncompromised results, this requires an educational approach distinctly different from and much more academically rigorous and technical than the skill-proficiency program effective for the training of the craftsman and commonly represented in the vocational-trade or "vocational-technical" programs which have evolved in tax-supported secondary schools and colleges under the Smith-Hughes Vocational Education Act.

The country-wide consensus among the Regional Committees of the National Survey was overwhelmingly to the effect that the technical-institute educational program, as defined and as currently needed, lies much closer to the professional levels of engineering than to the trade-skills and craft level of the vocational program. Here, it should be clearly understood that this is in no way a criticism of nor a reflection upon "vocational" education or the currently upgraded trade-training program as such, but merely a statement of proper relationship. There is a strong evidence that these critical distinctions too often are confused. This confusion is represented in the Defense Education Act of 1958, and in legislation currently under consideration in various states. A further comment is in order concerning the relationship existing between acceptable technical-institute curricula and the typical basic "pre-professional" curricula of the junior college or "lower-division" collegiate curricula leading to the engineering degree. At the risk of over-simplification, it may be said emphatically that the person who finishes the first two years of an engineering curriculum as presently cataloged by most of the ECPD-accredited engineering colleges and universities is NOT adequately prepared for productive employment as an engineering technician or as an engineer. Survey consensus is that such a person has too much of too little to qualify as an engineering technician on the one hand, and on the other hand he is only at the threshold of his professional engineering education.

Another point of major importance causes considerable confusion. This is the misguided idea that the zone of the Engineering Technician is the natural "dumping ground" for those who "can't make the grade" in engineering. This misunderstanding is unfortunately common among the counselors of students at both secondary and collegiate level. Survey consensus is that most of those unfortunate misfits who "cannot make the grade" in engineering would be just as miserable misfits in the field of the Engineering Technician. Consequently, the field of the Engineering Technician is no more logically

to be considered the "dumping ground" for misfit engineers than is the field of engineering logically to be considered as the "dumping ground" for misfit Ph.D.'s or physical scientists. These interrelated fields of human endeavor are co-equal in their importance to the whole social and economic—and professional—structure. They and the people in them—and the people who should be in them to provide the effective and satisfying balance of manpower distribution needed for our way of life—deserve to be accorded interrelated status and recognition.

Better Manpower Balance

Just as a large and growing segment of the engineering science of yesterday has become today's technology and as such is competently handled by qualified engineering technicians, so will much of today's expanding science become tomorrow's technology. As the frontiers of engineering science move on, there must be an ever-growing supply of competent manpower to keep the over-all engineering enterprise operating and growing. Recognition of the "Technical-Institute Idea" in higher education provides a logical channel for the expansion of total technological manpower without any "watering-down" or down-grading.

The quantitative aspects of this situation may be indicated by the fact that in the present national economy there is a confirmed need for qualified and properly prepared technicians in engineering and related technologies which numerically exceeds the much-talked-about need for scientists and engineers. From this fact it follows that one of the most productive ways to increase the effective total supply of engineering-scientific manpower is to co-ordinate the development and utilization of the Engineering Technician with the development and utilization of the Engineer. This presumes the courage to turn over to the engineering technician those segments of yesterday's engineering and science which have become today's technologies. And it must be recognized that these are very large segments. By doing this methodically and determinedly, a corresponding multiplication of the time and energies of qualified engineering-scientific manpower would be accomplished.

Changing Times Require Changing Concepts

Conditions have changed drastically in the relatively short history of engineering enterprise, and still are changing. Frontiers have moved, and still are moving. Manpower concepts, both social and professional, must keep pace. Both the concepts and the procedures relative to engineering science and related technologies as they affect the entire spectrum of technological manpower both educationally

and professionally obviously must change accordingly.

History reminds us that the earliest area of organized and co-ordinated human endeavor which can be called "engineering" was, as might be expected, military. Méchanical ingenuity, meager technical knowledge, and manual skills were co-ordinated with brain-power to devise "engines" and facilities for military purposes—the Trojan horse, for example. Later human ingenuity and growing knowledge were used to design and construct roads, bridges, aqueducts, and other facilities for the civilian population. This development was called "civil" engineering to distinguish it from the military. Then came mechanical and electrical engineering, and the broadening range of applied arts and sciences as the store of technical knowledge grew. All this is known—as history—but how often is it considered thoughtfully in the light of its ever-evolving sociological and educational impact?

In early days men engaged in what we have come to call "engineering" did not object to being called "electricians" or "mechanics." Even Charles P. Steinmetz, the "wizard" of early electrical science and education was mentioned in contemporary literature as an "electrician." In fact, what about the engineering colleges? The land-grant college system, which today includes many renowned engineering schools, was established to create "colleges of agriculture and *mechanic arts*"—no mention of "engineering." However, as the fields expanded, there came a change. Professional consciousness took form, and the professional-technical societies were founded—partly for self-education, and partly for mutual prestige and promotion. Even in engineering education it may be recalled that before the turn of the century the Society for the Promotion of Engineering Education was formed. Note the word "promotion." Even less than seventy years ago, engineering education itself was fighting for a niche of recognition and acknowledgment of respectability in the cloistered halls of traditional higher education. Today, technical-institute education is in a similar situation with respect to public and professional understanding and acceptance.

And that raises another question which is not too well settled: Just what is an "engineer"? Fifty years ago the scope of available technological and scientific information was of such proportions that the traditional four-year engineering curricula had a fair chance to cover the ground reasonably well. With continuing expansion of technical knowledge and growing realization of the new knowledge still to be learned or digested for later application, the engineering spectrum—educationally as well as professionally—must be re-evaluated and redivided.

Cardinal in the philosophy of technical-institute education is the

concept of the three-part "engineering team." In turning to employment of engineering technicians, the purpose is to assess the extent to which this concept is now reflected in employment policies and practices in industry.

The Engineering Team

In the beginning the function of the engineering technician was not clearly separate from the function of the engineer. One person performed, and in too many cases still performs, both functions. Failure to recognize this fact not only has interfered with proper and full recognition of the separate but intimately related functions, but also has allowed considerable inefficiency in utilization of manpower to take hold in today's industrial world.

It is instructive to consider why and how technical-institute education came into being apparently so long before the need for it began to be appreciated. Reflection upon this paradox brings to mind the claim of some engineers that engineering is one of the older professions, or at least occupations of mankind. According to this view, the first engineer was the man—or woman—who first supplemented his own bare-handed activity with some kind of instrument or tool that employed or made use of the forces or materials of nature. What seldom is fully recognized is that this same person was in effect a one man "engineering team"—the engineer who had the inspiration to conceive and apply knowledge or intuition, the engineering technician who completed the practical application, and the craftsman who made and used the tool. The builders who have been recognized in history continue to embody within one person the whole engineering team, though, as civilization progressed, master builders came onto the scene and began to delegate some of the functions of the craftsman to others. As working parties grew in size, the master builders naturally began to assume supervisory and management functions, so perhaps in this sense business administration also should be recognized as an old profession.

A still broader view will suggest that many builders and master builders were more than a one-man, or part of a two-man, engineering team. Many of them performed as project teams, in that they also combined with their engineering and technician functions some of the functions of architect, artist, salesman, and no doubt also of the psychologist and sociologist. Still others may also have doubled as philosophers. Further exploration of the historical basis is not germane to this present discussion, providing enough has been said to establish the point that, with reference to the past, one cannot talk about *the* engineering technician or *the* engineer as if each were one person who performed in a single capacity. Even in 1958

this cannot be said to apply universally. However, one result of the rapid discovery, formulation, and application of knowledge has been a continual trend toward greater specialization of manpower—that is, toward the necessary limitation of the activities of each of many individuals more to a single function or cluster of functions. Moreover, these broad categories of functions themselves have come to be sub-divided into sub-categories in several different ways. Thus the engineering technician of today will be an electronic technician, a construction engineering technician, or a refrigeration technologist, etc., while the engineer may be a research engineer, a design engineer, or a production engineer, etc.

Returning to the one-man engineering team of history, we certainly should not imply that the one-man team was or should have been conscious of the separate technical roles he performed. The three-part concept of the engineering team is the end result of a 200-year evolution in the human mind. The necessary basis for this concept was the incorporation of modern science into engineering. In turn, modern science can claim but a few centuries of existence, since it began only after a careful observation of nature was coupled with mathematics to produce the inductive, scientific method. Thus the three-part engineering team could not logically have been recognized more than a half-century ago—and then only by a person possessed of the extraordinary vision to foresee that the experiments of Galileo, so hotly disputed by contemporary scientific "authorities," would provide within a few hundred years a scientific base under the activities of the master builders, and thus introduce to the world the phenomenon of modern engineering. It took the catastrophic events of World War II to abbreviate the slowly narrowing time-lag between discoveries in basic science and their application in engineering. As the engineer became acutely aware of his relationship with the basic scientist, so he now has before him the conditions that bespeak recognition of his relationship with the engineering technician. Our Survey findings indicate that he has not fully and generally perceived this relationship.

The Demand—The Ratio of Engineering Technician to Engineer

One way by which to judge the extent to which engineering technicians have achieved recognition in industry is to determine how many are employed per engineer. As long ago as 1928 Spahr and Wickenden[1] found evidence to suggest that, nation-wide, the ratio of engineering technicians to engineers could become as much as 3 to 1

[1] William E. Wickenden and Robert H. Spahr, *A Study of Technical Institutes*, Society for the Promotion of Engineering Education, 1931, pp. 52–60.

in manufacturing industries. Although some companies in several types of industries have achieved this or a higher ratio, the Survey revealed that nation-wide the actual ratio in 1957–58 was much smaller. The employment records of approximately 90 companies of various kinds—in what may be called engineering industries—throughout the United States yielded an overall ratio of technicians to engineers of about 0.8 to 1. This result is the quotient of the total number of engineers in all these companies to the total number of identifiable engineering technicians in the same companies. The category "Engineers" as used here included those designated as "engineers" by the companies on the basis of the differentiation between engineers and technicians adopted for purposes of the Survey regardless of whether they had attained recognition by the bachelor's degree from an engineering college or by performance in lieu of this degree. Similarly, the category "engineering technicians" includes those formally trained in technical-institute curricula as well as those who by self-study and experience attained status as engineering technicians.

After they had given data on current (1957) actual employment of engineers and technicians, the interviewed employers were asked to estimate the ratios that they would like to have "now" (i.e. 1957), five years later and ten years later. Information obtained on this basis from 100 companies (including a few government agencies) may be summarized as follows, the figures being the ratios of engineering technicians to engineers:

1. Group A—Composite group of 100
   Existing 1957: Range 0 to ∞; Mean 1.1; Median 0.8
2. Group B—72 of the 100
   Existing 1957: Range 0 to ∞; Mean 1.1; Median 0.8
   Desired 1957; Range 0 to ∞; Mean 1.4; Median 1.0
3. Group C—50 of the 100
   Existing 1957; Range 0 to ∞; Mean 1.0; Median 0.7
   Desired 1957: Range 0 to ∞; Mean 1.3; Median 1.0
   Desired 1962: Range 0 to ∞; Mean 1.8; Median 1.3
   Desired 1967: Range 0 to ∞; Mean 2.2; Median 1.9

The zero to infinity range in the ratio of engineering technician to engineer occurred because a few industries were using engineering technicians but did not employ any engineers. The mean for each group was calculated by disregarding the infinity data. Two conclusions are obvious. The first is that there is a current identifiable shortage of engineering technicians. The second conclusion is that within the next decade employers would like to more than double the number of engineering technicians in proportion to the number of engineers. Since the number of employed engineers is expected to increase in the decade 1958–68, the demand for engineering technicians seems destined to grow even faster than is suggested by the foregoing data.

From a statistical viewpoint, it must be kept in mind that the foregoing conclusions about employment prospects are based upon data from a nation-wide sampling of employers which is presumed to be a representative (i.e. random) sample of all employers. Granted this assumption, the statistics derived from the data must be understood as general rather than precise indicators.

The Demand—Number of Engineering Technicians

These conclusions, based on ratios of technicians-to-engineers may be tested by analysis of another kind of estimates made by employers who participated in the Survey. These other estimates were expressed in terms of the actual numbers of engineering technicians employed in 1950–57 and estimated to be required by 1960–65. To permit comparison and analysis these data were normalized for each employer by designating his figure for 1957 as 100 per cent.[2] Straight lines were fitted (by the "least squares" method) to averages of the normalized estimates. Results are shown ln Figure 1. There it may be noted that line *X* indicates that the number of employed engineering technicians will increase by approximately 75 per cent for the

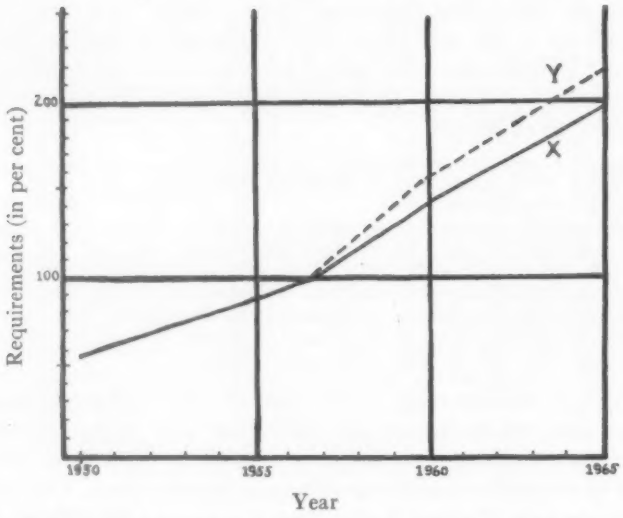

Fig. 1. Normalized requirements for engineering technicians (1957 = 100%).

Plotted points are mean values for:
X = 40 employers who employed technicians in 1950
Y = Same 40 employers plus 9 others who did not employ technicians in 1950

[2] The normalized indices are, of course, unweighted and therefore appropriate for comparison with estimated ratios, likewise unweighted.

decade ending with 1967. Line *Y*, however, suggests that the number will almost triple. The difference between these two lines is that line *Y*, which does not extend back to 1950, takes into account nine employers which did not exist in 1950, or, for reasons of policy did not employ engineering technicians at that time.

The rather large difference in slope between lines *X* and *Y* in Figure 1 means that the expected rate (9 and 18 per cent per year, respectively) of increase in the use of engineering technicians must be considerably greater for the additional nine employers than for the initial group of forty employers. However, the range is also greater for these nine employers which began to use engineering technicians since 1950, and consequently it cannot be assumed a priori that a new "user" of engineering technicians will become a significant source of employment for graduates of technical institutes.[3] The general conclusion which must again be emphasized is that the statistics on future employment of engineering technicians must be considered only as general indicators of possible trends. The precautions previously mentioned should therefore be applied to interpretations and applications of these data.

Engineering Technicians and Engineers on the Job

One of the best clues by which to gauge the effectiveness of existing utilization of engineering technicians by an employer is the attitude of supervisors and engineers of that employer toward the engineering technician and his role. Most Regional Committees found at least a few employers in whose firms or agencies engineering technicians were recognized and rewarded as co-equal parts of the engineering team.

[3] The ranges in indicated numbers of engineering technicians and normalized requirements for the initial group of 40 employers and the supplementary group of 9 are as follows:

Group	Employer	Estimated Requirements for Engineering Technicians							
		Numbers Required				Normalized Requirements (%)			
		1950	1957	1960	1965	1950	1957	1960	1965
40	A	1000	600	600	600	167	100	100	100
	B	80	85	90	95	94	100	106	112
	C	300	760	1500	3000	39	100	197	394
	D	40	70	140	300	57	100	200	430
	E	—	90	100	100	—	100	110	110
9	F	—	128	350	700	—	100	273	550
	G	—	2	6	11	—	100	300	550
To understand further the wide range of the potential market for technical-institute graduates, consider the following information given by three employers whose estimates were so far beyond those of other employers that their data were not inluded in the computations for Figure 9-1:									
	N	—	2	10	20	—	100	500	1000
	I	—	100	750	1000	—	100	750	1000
	J	—	4	36	96	—	100	900	2400

Yet for each employer of this sort, there were several others who did not know what engineering technicians are—or who claimed to know, but sooner or later revealed an inadequate understanding or the usual confusion with craftsmen. The latter are not necessarily the most discouraging for a technical institute to deal with, for some of them have not yet had good opportunities to become acquainted with engineering technicians. Some of them are willing to be enlightened. The group which has fixed but erroneous ideas about the "technician" is likely to present more difficult and persistent problems. Typical of this group is the erroneous conclusion, frequently difficult to dislodge, that engineering technicians are to perform only the routine, repetitive, or distasteful jobs that engineers *can* do but don't want to do. This group tends also to regard engineering technicians as persons who aspired to be engineers but were inferior in ability and therefore reluctantly had to accept "second-rate" education and occupation.

Such attitudes and misunderstandings also were found among regional and national bodies of professional and technical societies of engineers. This situation represents one of the reasons for the slowness of general acceptance in the United States of the technical-institute idea in higher education in spite of its long acceptance in other industrial nations. It points up also the need for better education of the general public—including professional educators as well as industry management—as to the actual dimensions of the technological manpower problem and potential and its relation to the educational pattern.

Though the Survey did not purposely inquire intensively into situations of this sort, some of the opinions nevertheless suggest that they result from careless evaluation of the positions and performances of engineering technicians. For example, an engineer in mid-career may be compared, by himself or his supervisors, with an engineering technician in his entry occupation. Therefore it is important in relationships with employers to be sure that engineering technicians and engineers are compared at corresponding stages in their careers.

In the early stages of his career, the engineering technician will probably work closely with and under the supervision of experienced engineers. Later he may become largely independent of the engineer or launch into a business venture of his own. Or he may remain associated with the engineer for most or all of his career. Where this happens, and where both engineering technician and engineer progressively develop competence, the relationship can become one of mutual dependence, with less emphasis on a sharp dividing line between their individual responsibilities and functions. Several examples of such a relationship were found, for instance, in representative research and development laboratories. On a given project, for example, the en-

gineer will bring forth the initial conception of a design, general performance criteria, and broad boundary conditions of a system. The engineering technician will begin to translate these into such terms that some of the specific characteristics and operating features of the several components of the system begin to emerge. But he will not proceed independently from this stage. Repeated consultations with the engineer will occur and may involve modification of some of the initial characteristics and features. The engineer will still be in the picture beyond the stage of working drawings and construction, for he and the engineering technician can profitably continue their joint concerns with the trial runs and evaluation of results.

Consider also the role that an engineering technician at midcareer or late in his career might play in the orientation and beginning stages of the professional development of the new engineering graduate on his first job. Because of the increasing emphasis that today's engineering college must place on the "science" of engineering in contrast to the "art" of its practice, the competent technician of long experience is in an excellent position to help the fledgling engineer begin to acquire the art of engineering practice that is so important in his first five years of professional development.

This is a very brief and general account, but it is by no means hypothetical.

Employment Areas

The areas of employment open to the engineering technician are as broad and varied as the areas traditionally associated with engineering and the physical sciences. The depth of penetration varies with local circumstances, but Survey findings indicate this to be growing steadily as the supply of qualified graduate engineering technicians grows and proves its productive capacity and potential.

A representative sample of the point-of-entry of the technical-institute graduate into professional employment is given in Tables 1 and 2. These data were developed by The Pennsylvania State University in a 1958 survey of the 1955, 1956, and 1957 graduates from its technical-institute curricula in Drafting and Design Technology and in Electrical Technology that lead to the Associate in Engineering degree. The actual occupational titles under which these 341 graduates were employed by 115 different companies are listed in Table 3. These give a clue to the scope and nature of openings available to graduate engineering technicians across the spectrum of the various technologies.

Survey conferences and findings brought to attention the fact that in different segments of American industry there are different responses to the concept of the engineering technician. These may be

TABLE 1

AREAS OF EMPLOYMENT ENTERED BY TECHNICAL-INSTITUTE GRADUATES IN DRAFTING AND DESIGN TECHNOLOGY OF THE PENNSYLVANIA STATE UNIVERSITY

Area of Employment	Graduates							
	1955		1956		1957		Total—3 yrs	
	No.	%	No.	%	No.	%	No.	%
Drafting	6	18.2	16	31.4	49	55.6	71	41.3
Sales and Service	3	9.1	2	3.9	2	2.3	7	4.1
Design	22	66.6	26	51.0	25	28.4	73	42.4
Engineering	2	61.1	2	3.9	10	11.4	14	8.1
Research and Development			5	9.8	2	2.3	7	4.1

TABLE 2

AREAS OF EMPLOYMENT BY TECHNICAL-INSTITUTE GRADUATES IN ELECTRICAL TECHNOLOGY OF THE PENNSYLVANIA STATE UNIVERSITY

Employment Area	Graduates							
	1955		1956		1957		Total—3 yrs	
	No.	%	No.	%	No.	%	No.	%
Research and Development	5	20.8	12	21.5	18	32.2	35	25.8
Engineering	9	37.6	13	23.2	17	30.3	39	28.7
Production	1	4.2	2	3.6	6	10.7	9	6.6
Electrical Design	4	16.6	12	21.5	6	10.7	22	16.2
Sales	4	16.6	10	17.7	6	10.7	20	14.6
Drafting	1	4.2	7	12.5	3	5.4	11	8.1

classified for convenience here as Segment A being the presently operating industries which were established prior to 1900. Segment B being those established prior to World War II, and Segment C being those which came into being out of World War II research and development. The 1958 Penn State study revealed that approximately 10 per cent of the graduates reported upon were employed by Segment A enterprises, 30 per cent by Segment B enterprises, and some 60 per cent by Segment C enterprises. This is a valuable clue to the present understanding in industry as to the potential manpower value of the engineering technician.

SALARY AND ADVANCEMENT POTENTIAL

The matter of reward to the individual attainable through life-

TABLE 3

ACTUAL OCCUPATIONAL TITLES UNDER WHICH THE 1955, 1956, AND 1957 GRADUATES OF THE PENNSYLVANIA STATE UNIVERSITY TECHNICAL-INSTITUTE CURRICULA IN DRAFTING AND DESIGN TECHNOLOGY AND ELECTRICAL TECHNOLOGY WERE EMPLOYED

Acoustical Technician	Junior Draftsman
Application Engineer	Junior Maintenance Engineer
Assistant Electrical Engineer	Junior Research Engineer
Assistant Engineer	Laboratory Technician
Assistant Research Engineer	Layout Draftsman
Associate Designer	Layout Man
Associate Engineer	Machine Designer
Checker	Mechanical Designer
Chief Draftsman	Methods Analyst
Chief Tool Designer	Methods Engineer
Class C. Design Engineer	Product Engineer
Computer Inspector	Project Engineer
Customer Engineer	Proposition Engineer
Design Draftsman	Quality Control Engineer
Design Engineer	Quality Control Tester
Detail Draftsman	Research Analyst
Draftsman	Research Assistant
Draftsman B	Research Technician
Electrical Designer	Reactor Operator
Electrical Draftsman	Roll Draftsman
Electrical Inspector	Sales Engineer
Electrical Technician	Service Engineer
Electronics Technician	Site Technician
Engineer	Special Tester
Engineering Aide	Structural Steel Detail Draftsman
Engineering Assistant	Supervisor
Engineering Draftsman	Senior Research Analyst
Engineering Technician	Stress Analyst
Estimating Engineer	Technician
Field Engineer	Technical Aide
First Class Controlman	Technical Assistant
Inspector	Test Engineer
Junior Bridge Designer	Time-Study Observer
Junior Design Engineer	Tool Designer

long occupation has at least three facets meriting mention here. First, there is the self-evident but too-often neglected fact that the basic reward to the individual comes from participation in a productive occupation which lies within the interests and aptitudes of the individual and which offers appropriate progressive challenge to his capacity. Another and commonly neglected factor is the matter of personal "net worth," financially speaking. This is of appreciable significance to the high-school graduate contemplating college. It can be shown—in fact, anyone can figure for himself from local data—that, in terms of total intervening educational costs and occupational earnings, the technical-institute graduate has a long head start on the four-year baccalaureate graduate. The third facet embraces

the matter of salary and opportunity for growth available to the technical-institute graduate.

Survey data from 92 technical institutes showed starting salaries for 1956 graduates ranging from $3000 (three institutions) to $6000 (two institutions) with the median at $4520. Some 52 of these institutions were clustered within a range from $3800 to $4500. The comparable median starting salary for four-year engineering graduates of 1956 was about $5500, according to information compiled by Engineers' Joint Council in 1958.

The previously mentioned 1958 Penn State survey provides the data presented in Table 4 showing the salary and advancement record of Associate Degree graduates of two technical-institute curricula.

TABLE 4

SALARY AND ADVANCEMENT RECORD AS OF 1958 FOR TECHNICAL INSTITUTE GRADUATES OF THE PENNSYLVANIA STATE UNIVERSITY

Year of Graduation	Drafting & Design Technology			Electrical Technology		
	1955	1956	1957	1955	1956	1957
Average Starting Salary	$4080	$4150	$4320	$3960	$4140	$4320
Average—1958 Salary	5496	4900	4716	5760	5184	4680
Increase (%)	34.7%	15.2%	9.2%	45.6%	25.2%	8.4%

WHAT OF THE FUTURE?

It is but fitting and proper to close this discussion on the theme of its opening—that the career potential for the engineering technician is as broad and varied as the field of engineering itself. As with all developments in human affairs the general realization and acceptance of this fact is evolving relatively slowly, with full measure of confusion, and against some opposition. However, the fact is established, and regardless of semantics the trend is growing—has even grown perceptibly in strength and direction since this Survey was initiated in 1956.

In substantial measure the rate and quality of growth depends jointly upon the quality of technical institute education accomplished and the perception and understanding (attitude) of engineering education and the engineering profession. Finally, may I urge again the desirability of maintaining the philosophical rather than the institutional approach.

The First Two Years of the Space Age

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Introduction

Where does the world stand relative to space vehicles as the third year of the space age begins? Since that memorable October 4, 1957, when the Russians shocked the rest of the world with the first successful satellite, there have been at least 35 American attempts to hurl scientific payloads into space. These launchings have produced 17 satellite bodies and three deep-space probes, plus 15 which failed to accomplish their intended missions. The Russians have announced only their successes—four firings which placed seven major objects into orbit around the earth plus two firings of long-range space probes. These are all so-called "civilian" missiles. There have also been many, many military missiles of the Nike, Redstone, Jupiter, Polaris, etc. types which have been successfully tested.

Recently President Eisenhower has terminated the space mission of the Army and has placed Werner von Braun and his 4300-man team under the civilian National Aeronautics and Space Administration (NASA) which had already taken over the Navy's missile program. Thus all civilian space-engine problems are now under one roof, but there are still separate civilian and military agencies performing overlapping functions.

The Satellite Picture

As of November 1, 1959, the number of successful launchings of earth satellites stands at 18. These launchings have placed 24 objects into stable elliptical orbits about the earth, 18 of them being instrumented satellites, the other six being final stage rocket carriers which separated from the satellite proper and became "dead" moons revolving about the earth. Only 13 of these 24 are still orbiting (November 10)—nine instrumented satellites and four rocket carriers. Fourteen of the 18 launchings have been American, the other four being Russian. To date, no other country has entered this phase of the space age.

A summary of data for the first seven satellites launched is given in School Science and Mathematics, LIX (January, 1959), 55–7. Data on the other 11 are given at the close of this article, but it might be instructive to point out unusual features of a few of the artificial moons. The second Russian Sputnik contained a dog who survived the acceleration of launching and withstood the phenomena of weightlessness for about a week. The American Vanguard I, the six-inch "grape-fruit," was hurled into such a large orbit that it will remain

aloft for at least 200 years, constantly beeping out radio signals powered by its solar cells.

The rocket carrier which accompanied the Russian Sputnik III was certainly the most looked-at of all the satellites. Its large size made it visible to the naked eye in the early evening and pre-dawn hours. During the summer of 1958, many a man on the street was thrilled by its flashing as it crossed the evening sky.

The Explorers I, III, and IV, were the first to map out the three intense cosmic radiation belts found to encircle the earth. Later space probes have confirmed these findings, but have found that the donut-shaped belts apparently have a hole above the magnetic poles through which man might safely travel.

The Atlas-Score, the largest of the American satellites was unique in that it took aloft a message from President Eisenhower which was relayed back to the earth upon demand. In its later trips it received messages from the earth, stored them on tape, then played them back upon demand at some later time.

The Discoverer satellites were the first to be sent into polar orbits above the north and south poles and were the first launched on America's west coast instead of from Cape Canaveral, Florida. They were designed to test feasibility of having a capsule re-enter the earth's atmosphere after having been slowed down by retro-rockets. The Explorer VI, called the "Paddlewheel," has four vanes containing 1,000 solar cells on each side (a total of 8,000), which furnish power for the transmission of radio signals.

The last Russian satellite, Lunik III, has the distinction of being the first earth-object to see the other side of the moon. This satellite, launched on the second anniversary of the beginning of the space age, circled the moon, took a picture of the face of the moon never seen by the earth and transmitted this image back to the earth. It is now in a very large and eccentric orbit about the earth, never coming closer than 25,000 miles and going as far away as 290,000 miles. This requires two weeks for a complete revolution, and carries it so far from the earth that there should be strong perturbations of its motion caused by the moon and the sun.

The most sophisticated of all the satellites is the American Explorer VII, the latest of the artificial moons (dubbed the "kitchen-sink" for obvious reasons). It is designed to measure, put on tape, then play back, information concerning at least seven different experiments ranging from radiation-balance and cosmic rays to temperature. Although Explorer VII will stay aloft 20 years, its solar-powered transmitters will automatically shut off at the end of a year.

Important Space Probes

In addition to the above spectacular and interesting satellites, there

have been at least seven space-probes which warrant special mention. On October 11, 1958, the United States attempted a moon shoot which missed the moon (by some 150,000 miles!), but did send the Pioneer I to a record altitude of about 80,000 miles where its weight was only 1/400 its earth value. This probe and the Pioneer III which attained an altitude of about 70,000 miles just two months later did much to establish the nature of the deadly radiation belts surrounding the earth.

About this same time, the Americans sent a rocket into space with a small monkey called "Reliable" who survived launching acceleration, weightlessness for several minutes, and re-entry deceleration with practically no change in his normal behavior. The experiments were successful, but unfortunately the monkey was drowned before he could be rescued from the ocean. However, about five months later a rocket containing the two monkeys Able and Baker was launched and the monkeys were successfully recovered after the acceleration, weightlessness, and deceleration periods. Their reactions indicate that these three phases of space flight are not serious problems.

Another probe of note is the Russian Lunik I or Mechta, fired on January 2, 1959, which whirled past the moon into space to become the first artificial planet of the sun. Its radio signals were picked up to a distance of nearly 400,000 miles from the earth, before its batteries went dead. Just one month after this Russian accomplishment, the Americans placed Pioneer IV into an orbit about the sun, thus producing Artificial Planet Two. Both of these launchings required velocities in excess of the escape velocity from the earth, 25,000 miles per hour or 7.0 miles per second.

On September 13, 1959, the Russians with Lunik II became the first to make a direct hit on the moon, indicating uncanny guidance control during the 35 hour trip, but probably contributing little of real scientific value to the knowledge of outer space, other than that this feat is possible. While mentioning space probes, the list would not be complete without stating that the X-15 rocket has already carried man on at least two powered flights and will soon be ready to place him into a satellite orbit about the earth.

In reviewing the above satellite and space probe data, it would seem, in spite of the fact that the Russians have launched only six noteworthy space vehicles, that there is little question of Russian supremacy in space flight. Whether the United States can overcome its two to five year lag of the Russian program is debatable. Possibly combining the now-overlapping functions of the civilian and military under one command might help. During 1960 the civilian space effort alone is to cost the Americans more than the 500 million dollars used during 1959, but more than the need for dollars is a need for definite

decisions to be made now to cover a long range plan. A start must be made now if the future is to bear fruit.

8. *Name:* American Atlas—Score. 1958 Zeta

Lifetime: December 18, 1958–January 21, 1959 (35 days).
Launching Vehicle: 244,000 pound Atlas, 1½ stage rocket; had 2 booster engines each with 150,000 pound thrust on side of main sustainer engine having 95,000 pounds thrust; entire rocket (minus booster) became satellite; guidance system controlled from the ground—not preset as in others.
Orbit Angle to Equator: 32°.
Period When Launched: 100 minutes; 1 hour 40 minutes.
Apogee and Perigee: 911 miles; 118 miles, 17,000 mph.
Size and Weight: 8,800 pounds (4½ tons) after burnout; 85 feet long×10 feet diameter.
Instrumentation: 150–200 pounds of instruments; tape recorder for receving and re-transmitting voice from earth; Radios: 107.94 mc; batteries went dead December 31.
Comments: Made 500 round trips. Had recorded voice of Eisenhower and played it back on signal from the earth. Recorded signals from earth, played them back later.

9. *Name:* American Vanguard II (Weather-eye). 1959 Alpha

Lifetime: Feburary 17, 1959—(Several decades).
Launching Vehicle: 72 ft Vanguard 3-stage; 2 liquid, 1 solid; (similar to the Vanguard I with some modifications); 22,000 pound, 90% fuel, satellite spins on own axis 50 rpm.
Orbit Angle to Equator: 33.2°.
Period When Launched: 125.9 minutes; 2 hours 6 minutes.
Apogee and Perigee: 2,086 miles, 14,000 mph; 329.4 miles, 18,000 mph.
Size and Weight: 20 inch sphere; 22½ pounds
Instrumentation: 2 photocells to measure reflection of sunlight from clouds, land and sea; covers about 25% of earth's land surface, mostly in northern hemisphere; tape recorder stored information during orbit—played back when triggered twice each orbit; Mercury batteries for photocells lasted 2 weeks. Radio transmitter battery lasted about 4 weeks (went off when over dark side of earth).
Comments: Called "weather-eye" satellite. 50 pound shell of 3rd stage also orbiting. Could be used to detect H-bomb explosions in Russia. No military surveillance. Tapes on earth fed into electronic machine to give crude aerial photos. Vanguard project taken over from Navy during fall 1958 by National Aeronautics and Space Administration (N.A.S.A.).

10. *Name:* American Discoverer I. 1959 Beta

Lifetime: February 28, 1959–March 17, 1959 (17 days).
Launching Vehicle: Modified Thor. 1st stage; satellite in 2nd stage.
Orbit Angle to Equator: 90° (Fired directly south to circle poles).
Period When Launched: 95.5 minutes; 1 hour 35 minutes.
Apogee and Perigee: 519 miles; 176 miles.
Size and Weight: 19 feet long; pencil shaped; 1,300 pounds.
Instrumentation: 40 pounds of telemetry equipment; radio in nose cone. Had scanner with compressed gas to keep aimed at horizon (did not function).
Comments: First satellite launched from Vandenberg Air Force Base, California. Nose cone shielding antennae did not jettison. Took 5 days to decide was in orbit. Radio signals were erratic. Due to Earth's rotation, moved west of south and west of north to go over polar regions.

11. *Name:* American Discoverer II. 1959 Gamma

Lifetime: April 13, 1959–April 26, 1959 (205 revolutions).
Launching Vehicle: Thor-IRBM Missile first stage; Second stage: Length 19

feet, diameter, 5 ft. Fuel, unsymmetrical dimethyl hydrazine and nitric acid.
Orbit to Equator: 90° (Polar orbit).
Period When Launched: 90.8 minutes; 1 hour 31 minutes.
Apogee and Perigee: 243 miles; 156 miles; average speed, 17,400 mph.
Size and Weight: 1,600 pounds, similar to Discoverer I.
Instrumentation: Had 40 pound nose capsule containing instruments to supply oxygen and control heat and pressure. Capsule with instruments parachuted to Earth in Norway, after retrorockets slowed it down enough to enter atmosphere.
Comments: Discoverer had all necessary instruments to keep small animals alive. (But no animals.) Parachute and instruments were to be caught by C119 Flying Boxcar planes during 17th orbit around Earth near Hawaii. Only partially successful. Launched from Vandenberg. Jets turned so traveled tail foremost, always horizontal. Second stage was really oriented space platform.

12. *Name:* American Explorer VI (Paddlewheel) 1959 Delta 2

Lifetime: August 7, 1959 (Expected lifetime about 2 years).
Launching Vehicle: 50 ton liquid fuel Thor IRBM; 150,000 lb thrust for 160 sec.; 2 ton Able liquid fuel; 7,500 lb thrust for 100 sec.; 500 lb solid fuel; 3,000 lb thrust for 40 sec.
Orbit Angle to Equator: 47.1°.
Period When Launched: 12 hours, 46 minutes.
Apogee and Perigee: 26,400 miles, 3,120 mph.; 153 miles, 23,000 mph.
Size and Weight: 26 inches diameter, 29 inches deep; 142 lb payload.
Instrumentation: Over 100,000 individual components; 4 vanes with 20 inch squares having 1,000 solar cells on each side (8,000 cells total); each cell about 7 milliwatts; energy stored in nickel-cadmium batteries; power supply weighs 30 lb; has 3 transmitters to measure electron density; provides data on dispersive power of atmosphere for Navy 15.5 transmitter; has 3 instruments to measure three levels of radiation in Van Allen layers; has search-coil magnetometer for strength of magnetic field; has photocell for limited view of earth; 2-1 watt transmitters, 108.06 and 108.09 mc., with third having undisclosed frequency; has 30 different operations controlled from ground stations.
Comments: Third stage carrier also a satellite and brighter than paddlewheel so is designated 1959 Delta 1. Motion at apogee is perturbed by moon, shortening life to 1/10. Has rocket to be fired later to increase or change orbit.

13. *Name:* American Discoverer V. 1959 Epsilon

Lifetime: August 13, 1959–September 28, 1959 (6½ weeks).
Launching Vehicle: Similar to other Discoverers, but Thor booster stages fueled with denser propellant.
Orbit Angle to Equator: 80.0°.
Period When Launched: 94.1 minutes; 1 hour, 34 minutes.
Apogee and Perigee: 457 miles; 135 miles.
Size and Weight: 19 ft. long, 5 ft. diameter; 1,700 lb with 195 lb recovery capsule.
Comments: Main purpose was to test recovery of capsules. Capsule separated Aug. 14 as planned, but gave no radio signal so lost (probably temperature too low, preventing batteries functioning properly). Parachute not released.

14. *Name:* Discoverer VI. 1959 Zeta

Lifetime: August 19, 1959–October 20, 1959 (2 months).
Launching Vehicle: Same as other Discoverers.
Orbit Angle to Equator: 84.0°.
Period When Launched: 95.2 minutes; 1 hour 35 minutes.
Apogee and Perigee: 528 miles; 131 miles.
Size and Weight: Same as Discoverer V with 300 lb payload.
Comments: Traveled "backward." Released capsule as planned on Aug. 20, but no power for radio nor parachute. Capsule not recovered.

15. *Name:* American Vanguard III. (Ice Cream Cone). 1959 Eta

Lifetime: September 18, 1959 (Expected lifetime 40 years).
Launching Vehicle: Same as other Vanguards.
Orbit Angle to Equator: 33°.
Period When Launched: 130 minutes; 2 hours, 10 minutes.
Apogee and Perigee: 2,330 miles, 12,630 mph; 319 miles, 18,600 mph.
Size and Weight: 100 lb, 50 lb payload, 50 lb third stage rocket; shaped like ice cream cone; made of magnesium and fiberglass; 20 inch sphere with 26 inch tube tapered from 6 inches to 12 inches.
Instrumentation: To measure earth's magnetic field, solar X-rays, temperatures inside and out, micrometeorites; radio equipment good for 3 months. 62 batteries, silver-zinc, weighing 22 lb.
Comments: Was last in Vanguard series; was third successful in 11 trials. Third stage rocket carrier remained attached to satellite, as separation of Vanguard II gave satellite wobble.

16. *Name:* Russian Lunik III. 1959 Theta

Lifetime: October 4, 1959 (Lifetime infinite if not perturbed by motion of moon).
Period: 15.4 days.
Apogee and Perigee: 292,000 miles; 25,300 miles.
Size and Weight: Satellite 614 lb; rocket carrier 3,420 lb with 345 lb instruments.
Instrumentation: Two radios, 39.986 and 183.6 mc. Has both solar and chemical batteries; probably has Geiger counters, etc. for cosmic radiation; has camera which transmitted radio image of far side of moon.
Comments: Most important act was to get picture of back side of moon, never seen on earth; orbit is so large, motion will be perturbed by moon and sun; orbit is at right angles to orbit of moon.

17. *Name:* American Explorer VII (Kitchen Sink). 1959 Iota

Lifetime: October 13, 1959 (Expected lifetime 20 years).
Launching Vehicle: 60 ton Juno II rocket, 76 ft. long; 4 stages.
Period When Launched: 101.3 minutes; 1 hour, 41 minutes.
Apogee and Perigee: 677 miles; 346 miles;
Size and Weight: 36 inches high, 30 inches in diameter; 91¼ lb payload.
Instrumentation: To study 7 experiments, radiation balance, lyman alpha ultraviolet, X-rays, cosmic rays, micrometeorites, space temperatures. Main purpose to study lower levels of cosmic radiation about earth. Has two transmitters, chemical batteries at 20 mc, other solar batteries at 108 mc; solar powered transmitter will report on six of 7 experiments.
Comments: Will stay aloft about 20 years, but transmitters will automatically go off after one year. Data obtained should aid in weather study.

18. *Name:* Discoverer VII. 1959 Kappa

Lifetime: November 7, 1959 (Lifetime probably several months).
Launching Vehicle: Thor-boosted two-stage, similar to other Discoverers.
Orbit Angle to Equator: 90° (polar orbit).
Period When Launched: 95 minutes; 1 hour, 35 minutes.
Apogee and Perigee: 550 miles; 104 miles.
Size and Weight: 310 pound capsule as part of 19 foot satellite; second stage rocket part of satellite; weight, 1,800 pounds; diameter, 5 feet.
Instrumentation: Radio transmitters; mercury batteries weatherproofed with heaters, insulation, absorptive paint; battery operated ejection apparatus and parachute.
Comments: Capsule was to be ejected on 17th trip around earth 27 hours after launching and was to parachute to land in Pacific southwest of Hawaii. Previous Discoverers had malfunctioned due to cold batteries. Capsule was not ejected.

Taking the School Out-of-Doors*

John W. Brainerd

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Schools undoubtedly started out-of-doors long before mankind invented structures. A boy was schooled by his father as they went on hunting trips or worked their digging sticks in primitive agriculture. A girl would learn from her mother as they prepared food, wove, made skins into clothing, or fashioned pottery. With civilization cradled in the more favorable environments, these educative occupations were out-of-doors or under meagre shelter.

As the invention of better tools gave man more efficiency in producing his needs, society became more complex. Some people of special ability became artisans while others carried on more menial tasks. As natural resources of an area were more skillfully handled, commodities were produced in excess of local needs; so exchange by transport and barter created commerce; and a commercial group arose. With this increasing social complexity, some men became rulers, some became masters of their trade, some became rich. Thus a privileged class developed consisting of people who recognized the power of special knowledge. They also, potentially at least, had more leisure than their fellow men, and their children did not have to go hunting with daddy for the next meal, nor did they have to winnow the grain or tend the sheep. They had leisure.

It so happens that the word *school* comes from a Greek word with the connotation of *leisure*, something which we are apt to forget in the bustle of modern education when we try to instruct everybody's children, not just those of the economically privileged. For centuries, school was a privilege of the privileged, usually in a city or occasionally in the more rural surroundings of a monastery, which again provided the requisite leisure. In either case, the site for this more formal endeavor was increasingly indoors. Man was seemingly becoming more independent of his natural environment. Then there were the valuable scrolls and, much later, books. These precious records of wisdom and tools of teaching merited the best housing possible. Also, scientifically inclined scholars began to accumulate instruments to help their research, astronomical instruments for instance, to aid the senses of inquiring minds; and scholars of the arts gathered art treasures. Protection of these aids to learning definitely tied the scholar to a school building; and gradually the concept of educational use of leisure changed to a concept of school as an indoor place of learning.

The industrial revolution and technological developments of the

* Basis of remarks made to the American Nature Study Society, Washington, D. C. December 27, 1958.

past hundred years have of course greatly increased man's social complexity. In spite of tremendously increased human populations, proportionately fewer people are needed to produce food and fiber and perform relatively unskilled tasks. Proportionately more people are needed to run machines which harness new sources of power. Shorter working hours in the so-called developed countries give men more leisure, more time to travel, to play, and to study. Thus we find that public education in the United States today is not just to educate for gaining a livelihood; it is also to teach people to use their leisure wisely (or to use older phrases, "to keep the children off the streets" because "Satan finds mischief for idle hands to do"). Wherever and whenever technological development breeds unemployment, this aspect, education-for-leisure, becomes increasingly important. Also, we in our technological Western culture must remember that half of humanity is still illiterate, and that half the race goes to bed hungry every night. Such disparity in distribution of knowledge and natural resources creates tremendous social problems for which the remaining democracies must find scholarly answers through education of the masses as well as the tutoring of the economic elite.

Is our modern indoor education adequate for helping us meet the social problems of exploding human populations, and without recourse to war? No, it is not. Why? Because man in his "progress" has largely lost touch with some of his basic relationships to nature. Our urbanizing populations are broadly ignorant of the resource-base of our crazy culture. They look at land as a place to erect a building or park a monstrous car, without adequately assessing the value of the land as a watershed, as fertile soil, or as beauty. How has our indoor education failed, and why?

The first half of the Twentieth Century saw science teaching go indoors as never before, using the improved microscopes to study microorganisms and tissues, using modern chemical concepts to analyse and synthesize new chemicals, using radio tubes and other miracles of the physical sciences to perfect new tools. Laboratory research became tremendously exciting, and is indeed becoming more so every day with work on nucleoproteins, photosynthesis, and radiation phenomena. Nor should we forget the fascinating new developments in the behavioral sciences. But now that we are well into the second half of the century, we are realizing increasingly that our culture and its educational processes lack the balance between knowledge of modern medicine and technological development on the one hand and knowledge of man's place in the natural environment on the other. We must not discredit the wonderful work that is being done, in such projects as the International Geophysical Year and its extension; rather we must see what more can be done to regain some of

the educational advantages that the cave man had before schools erected so many walls between modern man and his environment.

Thus we come to the challenge of taking the school outdoors again. Many teachers of course have been doing just this, unwilling to instruct only in caves, when there is such stimulating exploration just outside. But such teachers are too few. They often have disapproving administrators. They emerge from the building onto a desert pavement or an artificially maintained grassland where conformity to style has dictated uniformity of environment. And then the children feel that outdoors means liberation and, like hot coca cola with the top removed, they fizz all over uncontrolledly . . . . What can be done?

1. The teacher must explore the school grounds and neighborhood. If the teacher can't get fun poking around outdoors, noting patterns in the landscape which raise tempting questions, then he or she had better stay indoors—or give up teaching. For instance, just think of the research into microclimates, animal behavior, and physiology that a class could become absorbed in if challenged by a teacher's observation that there was more sparrow whitewash under one window sill than under the others! And think what it does for both motivation and memory for a class studying health to take a three-minute field trip (portal to portal) to find the opium poppy's relative, *Celandine*, growing weedily but beautifully under the classroom window, and to discover that the broken tip of the pod emits enough yellow sap, like a ball-point pen, to write the word POPPY. That is when the teacher's exploring really pays off.

2. The teacher must plan, first in the lonely aloneness of the true leader, then in the crazy, mixed-up turbulence of cooperative endeavor as the youngsters kick in their ideas, some impossible, some improbable, but some impeccable. If after a week or weeks of planning, the entire class makes a sortie in a quiet and businesslike manner, with each student or small group of students bringing back written and pictorial records which fall into place in a publishable class report correlated with their classroom work in, say, arithmetic and social studies, then all the planning pays off.

3. The students must go outdoors purposefully and stay busy. For making records, a home-made, masonite, $9'' \times 12''$ clipboard is useful; it can be designed to hang on the front of the students' desks when not in use. The $8\frac{1}{2}'' \times 11''$ sheets of field records are handier for classroom follow-up than are field notebooks. Sometimes it helps to mimeograph worksheets of this size beforehand, especially when base maps of the school grounds are involved.

There is no end to the possible student projects outdoors, such as mapping, making inventories of rocks, building and paving materials,

soil, water, vegetation, and animal life; recording changes, seasonal and other; planning for better management of the school grounds, zoning for more comprehensive use with outdoor classroom and theater, experimental garden, sand-modeling area, junglegym of trained living trees, experimental forest, wildlife management area, and natural areas to compare with managed areas. (In city schools these may have to be in miniature, but they can all be done!) Then the students can help carry out the plans, for instance actually making experiments such as writing the name of the school on the front lawn with fertilizer and making hypotheses as to how soon the principal will notice it. They can make an improvement cutting in the school forest (which in a city school may consist of only three Ailanthus seedlings, to be sure!) They can build a fence around the natural area (even though it may be only the unplanted half of a window box!) They can make "before-and-after" photographic records and use various arts to keep the rest of the school aware of the educational uses to which the school grounds are being turned.

4. The administration must give support. Approval from the boss is like oxygen for a flame: there must be at least a little. Surely it is the administrator's duty to foresee difficulties in any new project; but the capable administrator will help his teachers avoid or surmount these difficulties rather than smother their enthusiasm which is basic to all good teaching. He will not imprison a teacher in the classroom if that teacher can improve the class's work by moderate use of the school grounds or a neighboring park. Many school administrators have only the foggiest notion of the outdoors; most are willing to admit it and laughingly to start learning along with the teachers and youngsters, realizing that they will always be behind.

5. The custodian, whose good work is basic to the health and happiness of the children, must realize that a little mud in the corridors now and again is part of an important kind of education which is building better citizens and reducing vandalism. He will even lend a hand and tool occasionally if they have been appreciated and returned properly before. Eventually he will give support to the teacher's request for a lean-to shed for safe storage of outdoor tools, just for student use.

6. Parents, now mostly too busy to go hunting or hoeing every day with their children, must realize that today's school has taken over certain educational functions of the family but that this does not relieve the home of responsibility for helping the children integrate their school learning into the larger world. They must welcome and support a broader use of the school environment in preparing their children for a world with many social problems related to natural resources best studied in part outdoors.

A Major Experiment for Teaching Meaningful Electricity Fundamentals

R. E. Showers

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We all search for learning experiences which students enjoy and which we feel do a genuine job of teaching. Student comments on the following electricity experiment have been gratifying. The low cost of the basic equipment; the availability of components; ease of assembly; and the practicality of being drawn from the electronics field should enhance the experiment in the teacher's eyes. Most of all, this experiment can be a culminating laboratory effort after study of Ohm's law and Kirchoff's Laws. It can be the first experiment done in electricity and the students will have a genuine sense of accomplishment when they complete it. The equipment is extremely flexible so that better students can proceed to relatively complex understandings with ease.

Background

A survey of the basic electricity experiments presented in laboratory manuals stimulated a search for some kind of a laboratory experience that would point up Ohm's law and Kirchoff's Laws more realistically. To me, experiments with nichrome wire resistors and resistance boxes were inadequate.

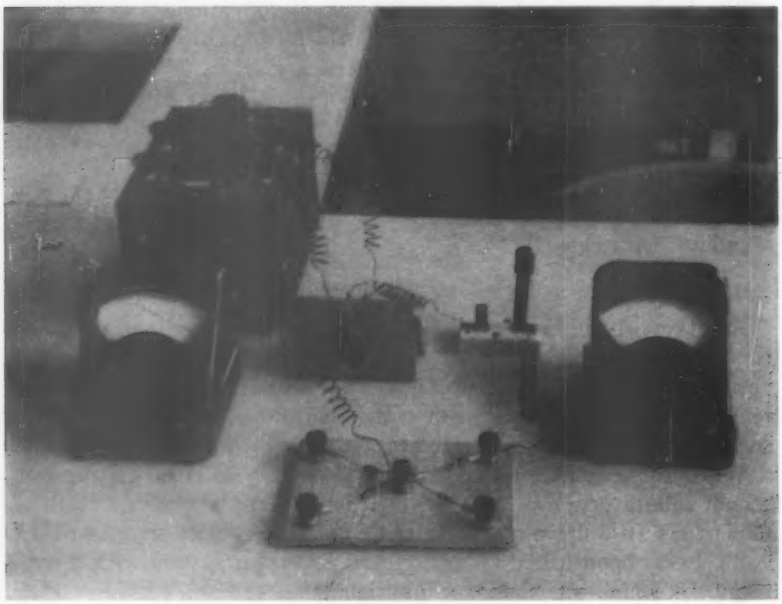
When the available equipment for the study of electricity in our school laboratory was examined, I found only ammeters with a monstrous 10 amp range and D.C. voltmeters with ranges of 15 volts. I was bequeathed an antiquated generator system with a battery bank which was no longer functional.

Plan

During the next three-year period specific equipment was acquired to implement the new program. Four rectifiers which would produce up to 8 volts D.C. were purchased. This was less expensive than rejuvenating the D.C. system of the laboratory. Four 10 watt 50 ohm wire wound potentiometers, twenty binding posts, and sixteen assorted carbon resistors of one watt rating were purchased. During the period four dual range milliammeters were purchased. These had ranges from *0–15* mils and *0–150* mils. We also found on the surplus market some excellent multirange voltmeters. These had ranges from 1.5 to 15 volts in three or four steps. We completed the equipment demands with one moderately priced multirange volt ohm multimeter.

The heart of the experiment is a resistor board. Four pieces of $4'' \times 6''$ plywood were cut from $\frac{1}{4}''$ stock. Five binding posts were

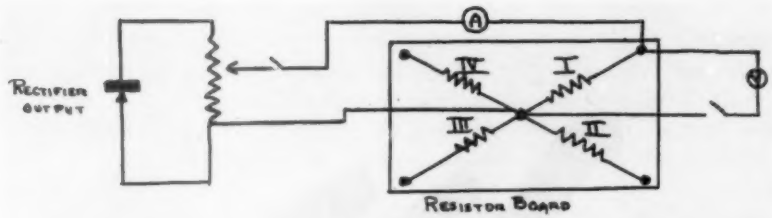
affixed; one in the center and one in each corner of the board. Such an arrangement allows the insertion of four resistors diagonally with a common center terminal. Two identical resistors were used as well as one low one and one of higher resistance. The four resistors were soldered to a common central lug and had a lug soldered on each of the other terminals so that the entire set-up was electrically sound and only binding post connections would be subject to a friction fit.

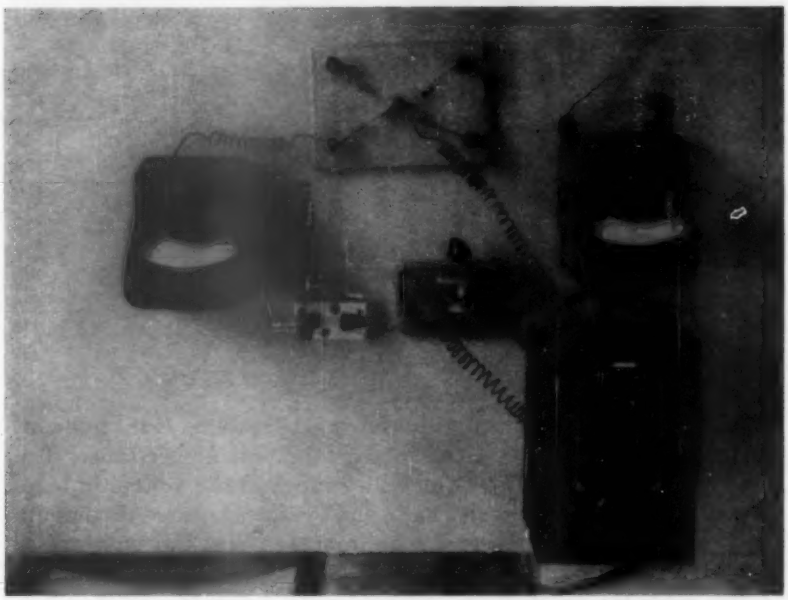


The Set-Up

Student Preparation

Before we undertake the laboratory work the class studies Ohm's law with emphasis on units and problem solving. Currents are introduced as milliamperes. When meters are studied emphasis is placed on the accuracy obtained near full scale and the errors introduced by reading less than half scale. When we take up Kirchoff's laws the fact that meters pass current received attention. Meters thus become associated with voltage drops and the meaning of internal resistance of a meter becomes more significant. The application of voltmeters in circuits is referred to as a "parallel" procedure, and hence the current flowing through a voltmeter is part of the current indicated in



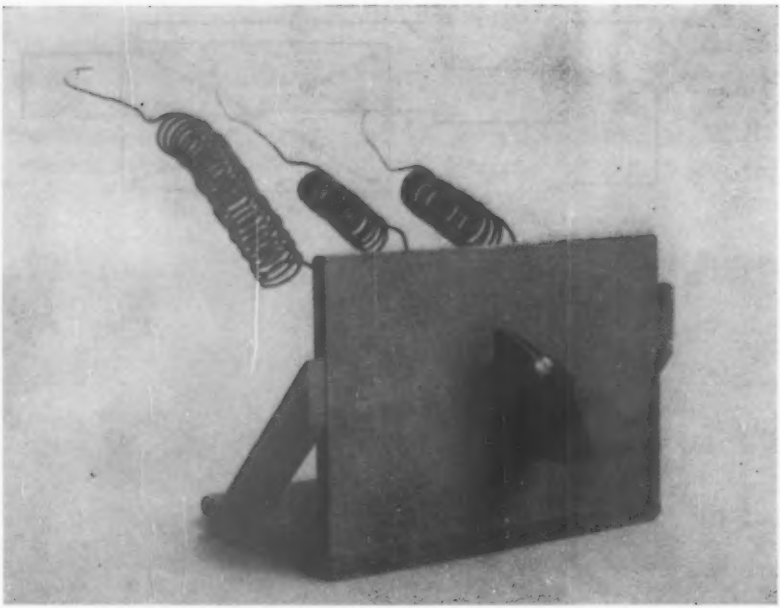


The Set-Up from above

the total circuit. The ohmmeter is studied as a self-contained Ohm's law circuit carrying its own source of EMF.

PROCEDURE

Students are cautioned to use the high scale of the milliammeter for each set-up. With only the switch in the main circuit closed the potentiometer is manipulated to give the highest "on scale" reading of the meter. If the next lower scale can be used, the range of the meter is lowered and once again the pot is adjusted. Assuming this is accomplished and the scale reading is adequately high it is recorded,



Potentiometer Mounting

and the voltmeter is momentarily closed for a reading. If the milliammeter goes off scale it must be put on the next higher range. The reading taken at the lowest "on scale" range of the voltmeter is recorded as the V of the circuit. The I and V values are used to compute R. Leads are now disconnected from from the board and the ohmeter applied across resistor I. The reading is compared with the calculated value. Since the resistors are standard radio types, the color code is read including the tolerance value. The color code value is recorded. Per cent error between the color code value and the experimental value is calculated. It should fall within the tolerance factor.

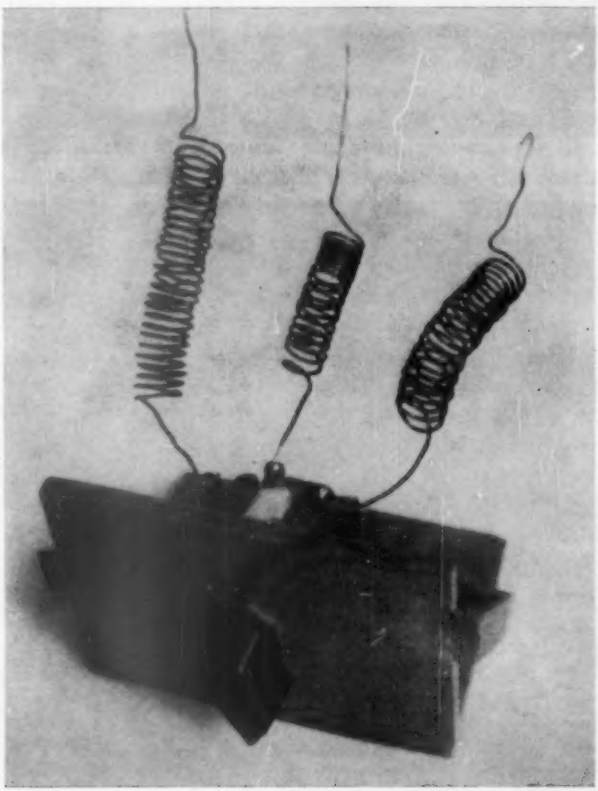
The same procedure is followed for resistors II, III, and IV and for the series circuits developed by using I and II, II and III, III and IV, and IV and I.

The students are now required to submit diagrams to show how V and I, for resistors I and II in parallel; II and III in parallel; III and IV in parallel; IV and I in parallel; and I and II in parallel with III in series with the parallel may be obtained.

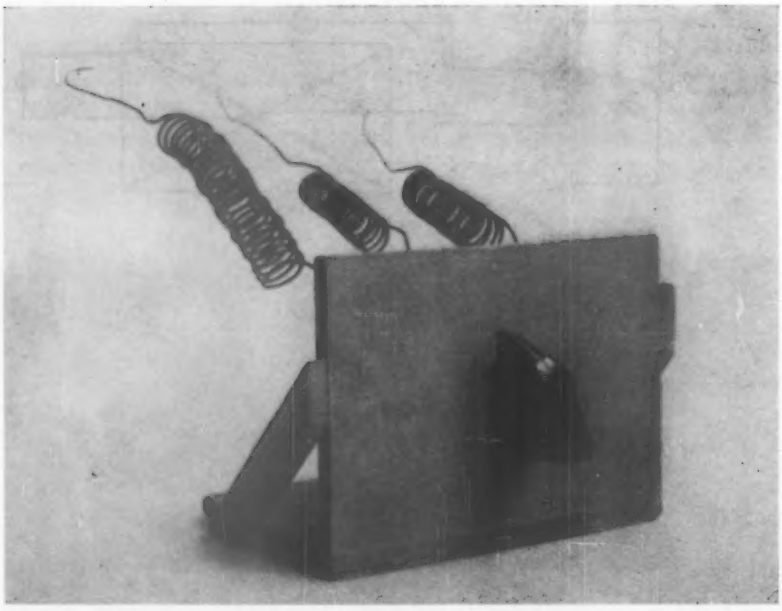
Experimental values for each resistance and the ohmmeter values are recorded. The theoretical value is obtained by doing a parallel problem using the color code values. Once again per cent error is calculated using the experimental value and the color code value.

The better students are encouraged to collect data on the multiple series and parallel circuits to demonstrate Kirchoff's laws. Current readings on the parallel set ups usually are very good but the voltage checks are never as convincing because the readings seldom are consistently high on the scales. The potentiometer control of current each time serves to increase the accuracy of the current readings.

This experiment has been a satisfactory learning device for a number of years. During this time no meters have been destroyed and there have been frequent expressions on the part of students that Ohm's law and Kirchoff's laws were more fully appreciated after working with the experiment. Budgetwise the equipment is not costly and it is easily replaceable from readily available parts. Perhaps it is time that we all review the appropriateness, the teaching efficiency, and the cost of our elementary electricity experiments.



Potentiometer Mounting



Potentiometer Mounting

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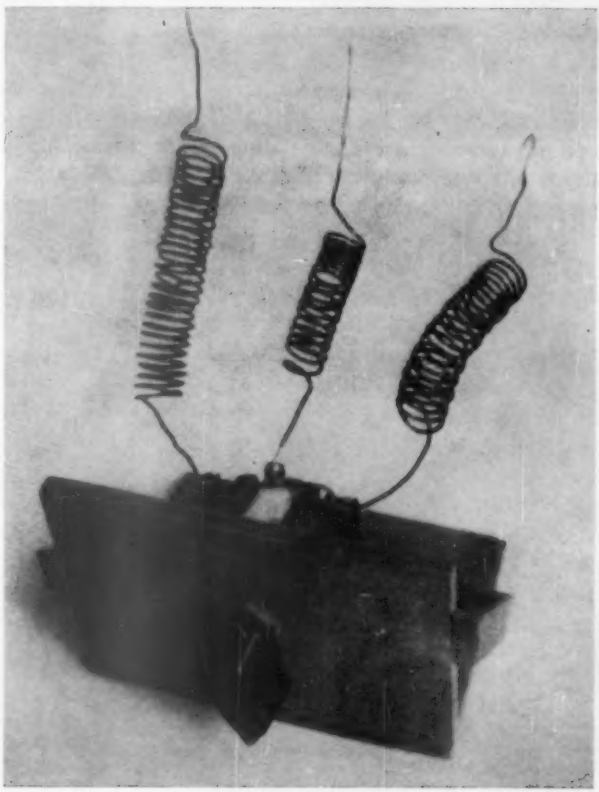
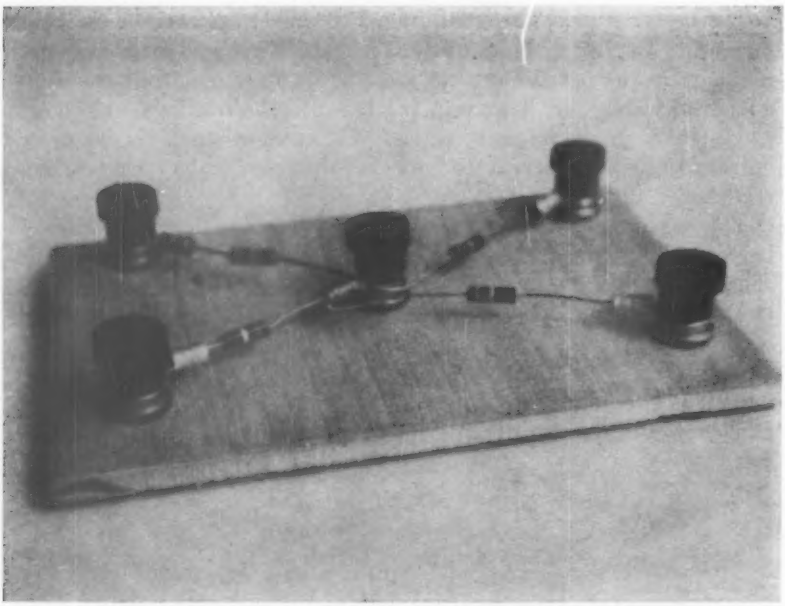
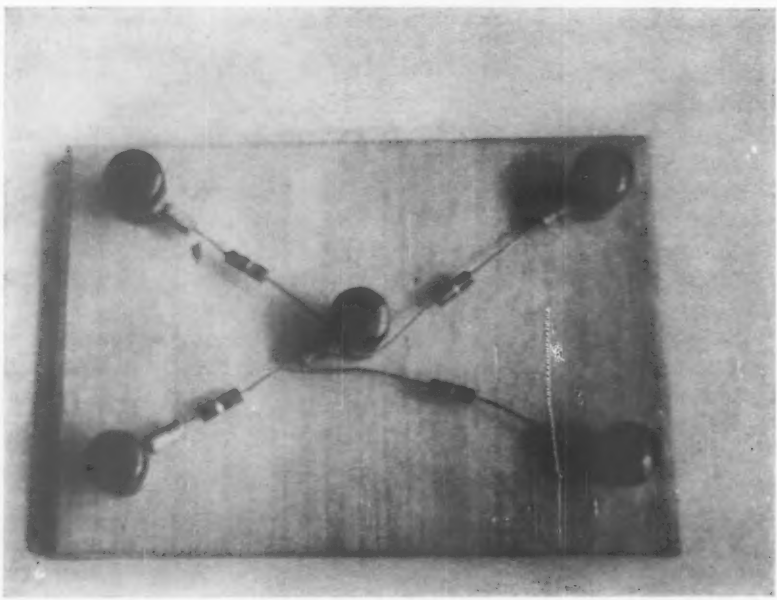


Potentiometer Mounting



Resistor Board



Resistor Board

Evolution of Pi: An Essay in Mathematical Progress from the Great Pyramid to Eniac

Panos D. Bardis

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If a man were robbed by the river of a part of his land, he would come to Sesostris and tell him what had happened; then, the king would send men to inspect and measure the degree to which the land had been diminished, so that in the future it should pay in proportion to the tax imposed originally. In this way, it seems to me, geometry was born and came to Greece.

Herodotus, *Historiai*, II, 109.

Introduction

The Nile's contribution to mathematics, the Queen of the Sciences, has been followed by innumerable developments, many of which were more spectacular than the one described by Herodotus. And while our mathematical knowledge advanced, numerous other fields, including the social sciences, achieved a higher degree of progress as the Queen of the Sciences became their most invaluable handmaid. Of course, since the natural, social, and psychological worlds are complex, mysterious, and unfathomable, what we know at the present time still constitutes only an infinitesimal fragment of the boundless realm of truth. That is why the real scientist—not the charlatan—often makes statements similar to the Socratic "I only know one thing—that I know nothing" or Galileo's proverbial "I do not know," and even reminds us of the genuine and spontaneous humility with which little Jo, in Dickens's *Bleak House*, constantly exclaims, "I don't know nothink about nothink at all." And his humility is reinforced considerably by the realization that the progress of his science, like that of every other field, has often been similar to the movement of a glacier, due to myriads of incorrect theories, unsound assumptions, and inadequate methods. Indeed, even in the history of mathematics we find many theories which have proved to be about as erroneous as Homer's famous reply to Hesoid concerning the number of Achaeans who went to Ilium, namely, "There were fifty hearths, and at each hearth were fifty spits, and on each spit were fifty joints of meat; and there were three times three hundred Achaeans around each joint" (Alcidamas, *Peri Homerou kai Hesiodou*, 319).

This last point may be partly illustrated by presenting some of the most important stages in the evolution of what William Jones has called π. Before doing so, however, it would be interesting to mention one of the most amusing mathematical paradoxes dealing with this value. According to Augustus De Morgan's *Budget of Paradoxes* (1872), Comte de Buffon (1707–88) asserted that, as Laplace proved later, the value of π may be calculated roughly by means of this

strange experiment: after drawing two parallel lines, at distance D apart, on a floor, throw a needle of length $L<D$. The probability that the needle will cross one of the parallel lines will then be $2L/D\pi$. Indeed, in 1855 Ambrose Smith of Aberdeen performed this experiment with 3,204 trials and found that $\pi=3.1412$. "A pupil of mine," De Morgan also informs us, "made 600 trials with a rod of the length between the seams, and got $\pi=3.137$."

At any rate, while reading numerous ancient, medieval, and modern mathematical and nonmathematical classics, I found many interest-in passages dealing with the circle ratio. Of these, I have summarized the most important ones for the present article, in which the items included have been classified both geographically and chronologically, as follows:

Japan. Yoshida Shichibei Koyu or Mitsuyoshi (1598–1672), who wrote *Jinko-ki* (Small Number, Large Number, Treatise), the first great Japanese work dealing with arithmetic, gave π as 3.16. Imamura Chisho, on the other hand, Mori's famous pupil, in his *Jugai-roku* (1639) states that $\pi=3.162$. The same value was given by Yamada (1656), Shibamura (1657), and Isomura (1660), while Muramatsu (1663), in the fourth book of his *Sanso*, which deals with the mensuration of the circle, gives π as 3.14, unaware of the fact that he had actually calculated the first eight figures of this value. Later, Nozawa (1664) and Sato (1666) also asserted that $\pi=3.14$.

In the seventeenth century, Japan's greatest mathematician was Seki, who discovered a type of calculus known as *yenri* (circle principle), the main problem of which may be represented by Oyama Shokei's (1728) formula,

$$a^2=4dh\left[1+\sum_{1}^{\infty}\frac{2^{2n+1}(n!)^2}{(2n+2)!}\cdot\left(\frac{h}{d}\right)^n\right],$$

where a stands for the length of the arc, d for the diameter, and h for the height of the arc. On the basis of this principle, in the next century, Matsunaga Ryohitsu calculated π to 50 figures. At about the same time, Takuma Genzayemon of Osaka employed the perimeters of polygons of 17,592,186,044,416 sides and computed π to 25 decimal places. Then, in 1769 Arima Raido, Lord of Kurume, published his *Shuki Sampo* in which he gives π to 29 figures by stating that

$$\pi=\frac{42822\quad 45933\quad 49304}{13630\quad 81215\quad 70117}.$$

In the sixth book of another mathematical treatise, Aida's *Sampo Kokon Tsuran* (1795), we find that

$$\frac{\pi}{2}=1+\frac{1!}{3}+\frac{2!}{3\cdot5}+\frac{3!}{3\cdot5\cdot7}+\frac{4!}{3\cdot5\cdot7\cdot9}+\cdots.$$

China. Ch'ang Hong (78–139), Emperor An-ti's minister and astrologer, believed that $\pi=\sqrt{10}$, while Wang Fan (229–67), an astronomer, asserted that

$$\pi=\frac{142}{45}.$$

Toward the end of the third century, what is known as "Chih's value of π" was given by Liu Chih as $3\frac{1}{8}$. One and a half centuries later, Wu, a geometer, stated that $\pi=3.1432+$. Tsu-Chung-Chih (430–501), however, gave an "inaccurate value," 22/7, and an "accurate value," 355/113, also stating that π is found between 3.1415926 and 3.1415927. Another geometer, Men (c. 575), took π as 3.14, while in the thirteenth century, Ch'in Kiu-shao, in his *Su-shu* or *Nine Sections of Mathematics*, gave π as 3, 22/7, and $\sqrt{10}$. Finally, Ch'en Chin-mo (c. 1650) took π as 3.15025.

India. After 327 B.C., when Alexander the Great invaded this country, India's mathematicians were influenced considerably by the mathematical works of the Greeks. This influence is partly indicated by many scientific terms which the Indians borrowed from various Hellenic writings. The Hindu scientists, for instance, used the word *kendra* for center—from the Greek *kentron*—and *jamitra* for diameter —from the Greek *diametros*. Long before Alexander's time, however, India had many brilliant mathematicians. Among them was Baudhayama (c. 500 B.C.), who, in one of the *Sulvasutras* (Rules of the Cord), suggests that the construction of a circle equivalent to a square may be achieved by increasing half the length of one side by one-third of the difference between itself and half the length of the diagonal, which means that $\pi=3.088$.

A thousand years later, in the celebrated *Paulisa Siddhanta*, a treatise on trigonometry, we find that $\pi=\sqrt{10}$. At about the same time, Aryabhata the elder of Kusumapura, the City of Flowers, wrote his famous *Aryastasata* in which the volume of the sphere is inaccurately given as $\pi r^2\sqrt{\pi r^2}$, which leads to $\pi=16/9$, undoubtedly a distortion of the Egyptian value

$$\left(\frac{16}{9}\right)^2,$$

computed by Ahmes. Then, in the sixth century, Aryabhata the younger wrote the *Ganita*, a poem in 33 couplets, the fourth of which deals with π as follows: "Add 4 to 100, multiply by 8, and add again

62,000; the result is the approximate value of the circumference of a circle of which the diameter is 20,000." Accordingly,

$$\pi = \frac{62{,}832}{20{,}000}$$

or 3.1416. In the next century, Brahmagupta (c. 628) used two values for π, the "practical" one or 3, and the "neat" one or $\sqrt{10}$. This last value was also employed by Mahavira the Learned (c. 850) in his *Ganita-Sara* (Compendium of Calculation), as well as by Sridhara (eleventh century) in his *Trisatika* (300 Couplets).

Babylonia. As early as 2100 B.C., the mathematicians of Babyloniā dealt with the circle ratio, but took it as 3.

Hebrews. The value 3 is also found in the Talmud, a collection of Hebrew books dealing with ceremonial regulations and laws, as well as in two passages of the Old Testament. According to the first of these, "And he made a molten sea, ten cubits from the one brim to the other: it was round all about, and his height was five cubits: and a line of thirty cubits did compass it round about" (I Kings, VII, 23). Similarly, the second passage reads as follows: "Also he made a molten sea of ten cubits from brim to brim, round in compass, and five cubits the height thereof; and a line of thirty cubits did compass it round about" (II Chronicles, IV, 2).

Egypt. One of the many fascinating theories dealing with the mystery of the Great Pyramid, which was built 5,000 years ago, is analyzed by Abbé Moreux in his *La science mystérieuse des Pharaons* (Paris, 1923, pp. 28–29), where he states: "Additionnons en effet les quatre côtés de la base du monument dont la valeur était primitivement de 232^m805; nous aurons pour le périmètre 931^m22: Soit: $4 \times 232^m805 = 931^m22$. Divisons maintenant la longueur de ce périmètre par 2 fois la hauteur de la pyramide qui était *à* l' époque de sa construction de 148^m208, nous trouverons la valeur de π." This means that

$$\pi = \frac{931^m22}{2 \times 148^m208} = 3.1416.$$

About one thousand years later, the famous Golenischev or Moscow Papyrus, which includes 25 mathematical problems, gave π as

$$\left(\frac{16}{9}\right)^2.$$

The same value is found in Ahmes's (moon-born; 1650 B.C.) *Directions for Obtaining the Knowledge of All Dark Things*, a book included in the Rhind Collection of the British Museum and containing 80

problems. Indeed, according to the fiftieth problem, the area of a circle may be calculated by deducting from the diameter 1/9 of its length and squaring the remainder, which means that

$$\pi = \left(\frac{16}{9}\right)^2 = 3.1604.$$

Greece. Archimedes (287–212 B.C.) dealt with the circle ratio in one of his most famous works, *The Measurement of the Circle*, which consists of three mathematical propositions. The third of these propositions reads as follows: "The ratio of the circumference of any circle to its diameter is less than 3 1/7 but greater than 3 10/71." A close approximation was also given by Claudius Ptolemy in A.D. 150 in his great treatise, *Megale syntaxis tes astronomias* (VI, 7), where he states that

$$\pi = 3 \cdot 8' \cdot 30'' = 3 + \frac{8}{60} + \frac{30}{3600} = 3.141,666 \cdots.$$

Michael Constantine Psellus (1020–1110), however, the Neoplatonist whom the Byzantine emperors called *Philosophon hypatos* (Prince of Philosophers), took π as $\sqrt{8}$.

Italy. Pietro della Francesca, an Italian painter, in 1475 published his *De corporibus regularibus*, in which he discussed his famous problem of the regular octagon by stating that "Diameter circuli qui circumscribit octagonum est 7," and using π as 22/7.

Switzerland. Leonhard Euler, one of the greatest mathematicians, popularized the symbol π in 1737, but this was not the first time that the circle ratio was represented by the sixteenth letter of the Greek alphabet.

France. François Vieta (1540–1603), a great expert in deciphering the cryptic writing of diplomatic documents and one of the first to introduce letter symbols in algebra, employed one of the earliest methods of computing the value of π by means of infinite products. He thus stated that

$$\frac{2}{\pi} = \sqrt{\frac{1}{2}} \cdot \sqrt{\frac{1}{2} + \frac{1}{2}\sqrt{\frac{1}{2}}} \cdot \sqrt{\frac{1}{2} + \frac{1}{2}\sqrt{\frac{1}{2} + \frac{1}{2}\sqrt{\frac{1}{2}}}} \cdots.$$

More than a century later (1719), De Lagny gave π to 127 places.

Germany. Albertus de Saxonia (1325–90), the bishop of Halberstadt, considered π equal to 3 1/7. On the other hand, in the sixteenth century, Ludolf van Ceulen became famous by devoting many years to the calculation of the circle ratio, which he gave to 20 decimal places in his *Van den Circkel*, and later to 35 in his *De arithmetische*

en geometrische fondamenten. This achievement was regarded so important that the value of π was cut on his tombstone in St. Peter's churchyard at Leyden, and, in addition, the circle ratio was named "Ludolf's number"—this term is often employed by mathematicians even at the present time. Then, π was computed to 140 places by Georg Vesa in 1793, to 205 by Zacharias Dase in 1844, and to 250 by T. Clausen in 1847, while in 1882 F. Lindemann proved the transcendence of π, a discovery that led to Kronecker's well-known question, "Of what value is your beautiful proof, since irrational numbers do not exist?"

Netherlands. Adriaen Anthoniszoon or Metius (1543–1620) took 355/113 as the value of π, and Adriaen van Roomen of Louvain (1561–1615), in his *Ideae mathematicae*, gave π to 17 decimal places.

England. Finally, John Wallis (1616–1703), a brilliant cryptologist and one of the founders of the Royal Society, gave one of the first values of the circle ratio involving infinite products. Thus, his well-known product for π is

$$\frac{\pi}{2}=\frac{2}{1}\,\frac{2}{3}\,\frac{4}{3}\,\frac{4}{5}\,\frac{6}{5}\,\frac{6}{7}\cdots\frac{2k}{2k-i}\,\frac{2k}{2k+i}\cdots.$$

Another founder of the Royal Society, Lord Brouncker (1620–84), through his work on the quadrature of the circle, discovered that

$$\frac{4}{\pi}=\cfrac{1}{1+}\,\cfrac{1^2}{2+}\,\cfrac{3^2}{2+}\,\cfrac{5^2}{2+}\cdots.$$

Then, in 1705 Abraham Sharp computed π to 72 places, while in 1706 an important step was taken by William Jones, who, on page 263 of his *Synopsis palmariorum matheseos*, for the first time expressed the circle ratio by means of the symbol π. The passage referring to this matter reads as follows: " . . . in the *Circle*, the Diameter is to the Circumference . . . 3.14159, &c.$=\pi$" (π is the initial letter of the Greek word *periphereia*, which means periphery or circumference). In the same year, John Machin, a professor of astronomy in London, calculated π to 100 decimal places, and, finally, in 1853 W. Shanks gave 707 figures!

Before closing, I should also add this last item: a few years ago, thanks to various modern scientific developments, the calculating machine known as ENIAC took only 70 hours and correctly computed π to 2,035 decimal places!

PROBLEM DEPARTMENT

Conducted by **Margaret F. Willerding**

San Diego State College, San Diego, Calif.

This department aims to provide problems of varying degrees of difficulty which will interest anyone engaged in the study of mathematics.

All readers are invited to propose problems and to solve problems here proposed. Drawings to illustrate the problems should be well done in India ink. Problems and solutions will be credited to their authors. Each solution or proposed problem sent the Editor should have the author's name introducing the problem or solution *as on the following pages.*

The editor of the Department desires to serve her readers by making it interesting and halpful to them. Address suggestions and problems to Margaret F. Willerding, San Diego State College, San Diego, Calif.

SOLUTIONS AND PROBLEMS

Note. Persons sending in solutions and submitting problems for solutions should observe the following instructions.

1. Solutions should be in typed form, double spaced.

2. Drawings in India ink should be on a separate page from the solution.

3. Give the solution to the problem whih you propose if you have one and also the source and any known references to it.

4. In general when several solutions are correct, the one submitted in the best form will be used.

LATE SOLUTIONS

2666. *John Stoddard, Piqua, Ohio*

2666. *LaFayette King, Bennington, Vt.*

2666. *James Wilson, Halifax, N. S., Canada*

2666. *Clara Broadhead, Fayette, N. Y.*

2683. *Proposed by Cecil B. Read, University of Wichita, Wichita, Kan.*

For every integer n greater than unity, prove that

$$1/1+1/2+\cdots+1/n<\sqrt{2n-1}$$

Solution by Leon Bankoff, Los Angeles, Calif.

It is apparent that

$$1+1/2<\sqrt{3}$$
$$1+1/2+1/3<\sqrt{4}$$

and that

$$1+1/2+1/3+1/4<\sqrt{5}.$$

Furthermore, if $n\geqq 5$, then

$$\sqrt{n+1}-\sqrt{n}>1/n.$$

Hence

$$\sqrt{6}-\sqrt{5}>\tfrac{1}{5}$$
$$\sqrt{7}-\sqrt{6}>\tfrac{1}{6},\text{ and so on.}$$

We may therefore write, for $n\geqq 2$,

$$1+1/2+\cdots+1/n<\sqrt{n+1},$$

which is a sharper inequality than the one to be demonstrated; because, if $n \geq 2$, then $2n-n \geq 2$ and $2n-1>n+1$.

Hence

$$\sum_{1}^{n} \frac{1}{n} < \sqrt{n+1} < \sqrt{2n-1}.$$

Solutions were also offered by Bjarne Skaug, Oslo, Norway; C. W. Trigg, Los Angeles, Calif.; Alan Wayne, Baldwin, N. Y.; and the proposer.

2684. *Proposed by J. B. Love, St. Davids, Pa.*

Given any triangle with angles A, B, and C, and with opposite sides a, b, c. Show that

$$\frac{\pi}{3} \leq \frac{aA+bB+cC}{abc} \leq \frac{\pi}{2}.$$

Comment by C. W. Trigg, Los Angeles City College

The proposition is dimensionally unfeasible. Consider an equilateral triangle with side k, then

$$\frac{aA+bB+cC}{abc} = \frac{3k(\pi/3)}{k^3} = \frac{\pi}{k^2}.$$

By varying the magnitude of k, the expression π/k^2 may be made to take on any desired value.

A solution was also offered by W. R. Talbot, Jefferson City, Mo.

2685. *No solution has been offered.*

2686. *Proposed by Brother Felix John, Philadelphia, Pa.*

Show that every prime factor is contained in $(n+r)!$ as often at least as it is contained in $n!r!$

Solution by C. W. Trigg, Los Angeles City College

It is well-known that the binomial coefficient

$$C(n+r, n) \equiv (n+r)!/n!r!$$

is an integer. The proposition follows immediately.

A solution was also offered by Alan Wayne, Baldwin, N. Y.

2688. *Proposed by Donald Byrkit, West Chicago, Illinois.*

Determine the radius of the circumscribed circle of the triangle whose sides are consecutive integers if the radius of the inscribed circle is $\sqrt{5}$.

Solution by W. R. Talbot, Jefferson City, Missouri.

Let the sides be $a-1$, a, $a+1$. Then the semi-perimeter, p, is $3a/2$ and the area, S, is

$$\sqrt{p(p-a)(p-a+1)(p-a-1)} = \frac{a}{4}\sqrt{(3a^2-12)}.$$

There are the familiar relations $rp=S$ and $4RS=abc$ where r and R are in the inradius and circumradius respectively. Substituting in $rp=S$ we get

$$6\sqrt{5} = \sqrt{(3a^2-12)} \quad \text{or} \quad a=8.$$

Then in $4RS=abc$, we get $R=21/2\sqrt{5}$.

Solutions were also offered by Leon Bankoff, Los Angeles, Calif.; Merrill Barneby, Tougaloo, Miss.; Felix John, Philadelphia, Pa.; C. W. Trigg, Los Angeles, Calif.; and the proposer.

Editor's Note: For a time each student contributor will receive a copy of the magazine in which his name appears.

2683, 2684, 2686, 2688. *Lee H. Mitchell, University of Michigan.*

PROBLEMS FOR SOLUTION

2707. *Proposed by Merrill Barnebey, Tougaloo, Miss.*

Sometime in the early 1920's a party of surveyors in California were faced with the problem of dividing a trapezoidal piece of land into two equal portions by means of a line parallel to the two parallel sides. Solve this problem for the surveyors.

2708. *Proposed by Cecil B. Read, Wichita, Kan.*

The number $abcd$ has the property that $(ab+cd)^2=abcd$. Find the number.

2709. *Proposed by Leo Moser, University of Alberta.*

A club consisting of ten members dècided to form a number of committees of various sizes. No member was to belong to more than one committee. After the number and size of the committees had been tentatively set, one member suggested that each committee should be increased in size by one. He claimed that this would increase the number of ways of choosing the committees. Another member countered with the statement that the number of ways of choosing the committees would be decreased. A third said that both were wrong. He was right. What was the size of the committees as originally proposed?

2710. *Proposed by C. W. Trigg, Los Angeles, Calif.*

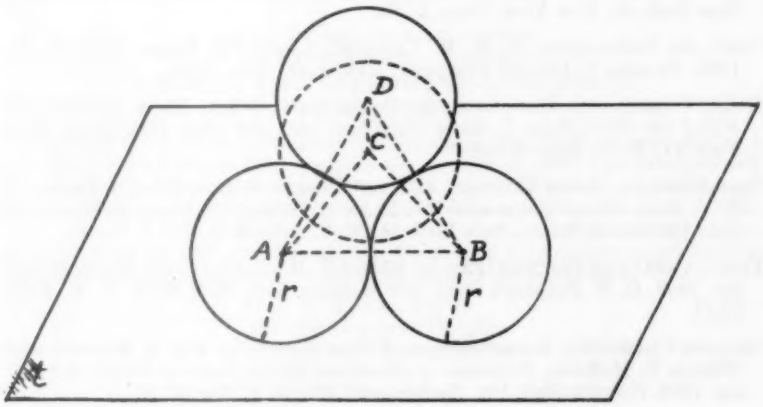
Through the foot of the altitude, CD, to the hypotenuse of the right triangle ABC a line is drawn parallel to BC meeting AC in E. Find the area of ABC in terms of EC and angle A.

2711. *Proposed by John Nayler, Alberta, Canada.*

The centers of four equal circles of radius R are at the corners of a square of side R. Find the area common to all four circles.

2712. *Proposed by Brother Felix John, Philadelphia, Pa.*

Three spheres of equal radii r rest on a table so that each is tangent to the other two. Another sphere with radius r rests on the three spheres. Find the distance from the fourth table to the sphere.



Books and Teaching Aids Received

THE CHEMICAL ELEMENTS, by Helen Miles David, revisions by Glenn T. Seaborg. Paper. 197 Pages. 10×18 cm. 1959. Science Service, Inc., 1719 N. St., N.W., Washington 6, D. C., and Ballantine Books, Inc., 101 Fifth Ave., New York 3, N. Y. Price $.50.

EVERYDAY LIFE IN PREHISTORIC TIMES, by Marjorie & C. H. B. Quennell. Cloth. 225 Pages. 13×21.5 cm. 1959. G. P. Putnam's Sons, 210 Madison Ave., New York City, N. Y. Price $3.50.

THE ARITHMETIC OF FLYING, by Secondary Mathematics Curriculum Committee. Paper. 41 Pages. 21×28 cm. 1959. National Aviation Education Council, 1025 Connecticut Ave., N.W., Washington 6, D. C. Price $.50.

DEVELOPMENT AND STRUCTURE OF THE FROG, a photographic study, by Addison E. Lee, Earl R. Savage, and W. L. Evans. Paper. Pages iv+44. 18×25 cm. 1959. Rinehart & Company, Inc., 232 Madison Avenue, New York 16, New York. Price $1.00.

ARE YOU A GOOD TEACHER?, by William M. Alexander, *Professor of Education*. Paper. Pages vi+57. 15×23 cm. 1959. Rinehart & Company, Inc., 232 Madison Ave., New York 16, New York.

PURCHASE GUIDE FOR PROGRAMS IN SCIENCE, MATHEMATICS, MODERN FOREIGN LANGUAGES, by Council of Chief State School Officers. Paper. Pages viii+336. 21.5×27.5 cm. 1959. Ginn and Company, Statler Building, Boston 17, Mass. Price $3.95.

MODERN HIGH SCHOOL BIOLOGY, a recommended course of study, by Dorothy F. Stone. Paper. Pages viii+96. 13.5×21 cm. 1959. Bureau of Publications, Teachers College, Columbia University, New York 27, New York. Price $1.50.

LABORATORY PERFORMANCE TESTS FOR GENERAL PHYSICS, by Haym Kruglak, *Western Michigan University*, and Clifford N. Wall, *University of Minnesota*. Paper. 165 Pages. 15.5×23.5 cm. 1959. Western Michigan University, Kalamazoo, Michigan.

STARSHIP TROOPERS, by Robert Heinlein. Cloth. 309 Pages. 12.5 20 cm. 1959. G. P. Putnam's Sons, 210 Madison Ave., New York City, New York. Price $3.95.

COLLEGE ARITHMETIC, by W. I. Layton, *Professor of Mathematics*. Cloth. Pages ix+200. 13.5×21.5 cm. 1959. John Wiley & Sons, Inc., 440 Fourth Avenue, New York 16, New York. Price $3.50.

TOPS AND GYROSCOPES, by R. W. Campbell. Cloth. 174 Pages. 14.5×22 cm. 1959. Thomas Y. Crowell Company, New York, New York.

R-L-C COMPONENTS HANDBOOK, by David Mark. Paper. Pages v+146. 13.5 ×21.5 cm. 1959. John F. Rider Publisher, Inc., 116 West 14th Street, New York 11, N. Y. Price $3.50.

SOAP-BUBBLES, THEIR COLOURS AND THE FORCES WHICH MOULD THEM, by C. V. Boys. Paper. Pages xv+193. 13.5×21.5 cm. 1959. Dover Publications, Inc., 180 Varick Street, New York 14, N. Y. Price $.95.

FIND A CAREER IN PHOTOGRAPHY, by Robert E. Hood. Cloth. 159 Pages. 13×20 cm. 1959. G. P. Putnam's Sons, 210 Madison Ave., New York, N. Y. Price $2.75.

ORGANIC CHEMISTRY, Second Edition, A Brief Course, by Ray Q. Brewster and William E. McEwen, *Professors of Chemistry*. Cloth. Pages xii+401. 14.5×23 cm. 1959. Prentice-Hall, Inc., Englewood Cliffs, N. J. Price $7.50.

INDUSTRIAL MATHEMATICS, by Matthias A. Thies, *Supervisor, Vocational School, Administrative Assistant, Boeing Airplane Company.* Cloth. Pages ix+342. 14.5×23 cm. 1959. Prentice-Hall, Inc., 70 Fifth Ave., New York 11, N. Y. Price $9.00.

BOBWHITE FROM EGG TO CHICK TO EGG, by Elizabeth & Charles Schwartz, *Biologists, Missouri Conservation Commission.* Cloth. 46 Pages. 15×20 cm. 1959. Holiday House, 8 West 13th Street, New York 11, N. Y. Price $2.50.

MEN, PLANETS, AND STARS, A Science Survey Book, by Clyde Clason. Cloth. 160 Pages. 14.5×20 cm. 1959. G. P. Putnam's Sons, 210 Madison Ave., New York City, N. Y.

CHICAGO SCHOOLS JOURNAL, Free and Inexpensive Teaching Aids for Science Education, Compiled by Muriel Beuschlein, *Chicago Teachers College.* Paper. 71 Pages. 15×23.5 cm. October, 1959. Chicago Teachers College, 6800 Stewart Ave., Chicago 21, Illinois.

CONTINUITY AND NUMBER, by B. Goussinsky. Paper. 31 Pages. 15×22 cm. 1959. Cultural Council of the General Federation of Labour in Israel, 5, Rosenbaum Street, Tel Aviv, Israel. Price $.50.

PROPERTIES OF MATTER, Third Edition, by F. C. Champion, *M.A., Ph.D., Reader in Physics,* and N. Davy, *D.Sc., M.Sc., Reader in Physics.* Cloth. Pages xvi+333. 14×22 cm. 1959. Philosophical Library, Inc., 15 East 40th Street, New York 16, New York. Price $10.00.

UNIVERSITY MATHEMATICS, A Textbook for Students of Science & Engineering, by Joseph Blakey, *Ph.D., Lecturer in Mathematics.* Cloth. 581 Pages. 14×21.5 cm. 1959. Philosophical Library, Inc., 15 East 40th Street, New York 16, N. Y. Price $10.00.

ROCKETS OF THE NAVY, by Erik Bergaust. Cloth. 49 Pages. 17×27 cm. 1959. G. P. Putnam's Sons, 210 Madison Ave., New York City, N. Y. Price $2.50.

SATELLITES AND SPACE PROBES, by Erik Bergaust. Cloth. 47 Pages. 17.5×27 cm. 1959. G. P. Putnam's Cons, 210 Madison Ave., New York City, N. Y. Price $2.50.

STUDIES IN MATHEMATICS EDUCATION, A Brief Survey of Improvement Programs for School Mathematics. Paper. 56 Pages. 13.5×21.5 cm. 1959. Scott, Foresman and Company, Chicago, Illinois. Price $.50.

EDUCATIONAL TESTING SERVICE
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VISITING ASSOCIATESHIP IN EDUCATION

SUMMER 1960

The Test Development Division of Educational Testing Service is offering a Visiting Associateship in Education for the summer of 1960. The Associate will be concerned with problems connected with the development of professional examinations for teachers either in the area of science or general education. The basic stipend is $800, plus transportation costs of the Associate and additional allotments up to $300 for dependents. Completed applications must be submitted by February 29, 1960. Applications may be obtained from

Mrs. W. Stanley Brown
Test Development Division
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20 Nassau Street
Princeton, New Jersey

Book Reviews

MATHEMATICS TO USE, by Mary A. Potter, *Consultant in Mathematics, Racine, Wisconsin*. Cloth. Pages viii+504, 16×24 cm. 1959. Ginn and Company, New York. Price $3.72.

This book is a newly revised edition of a popular textbook written by Mary Potter and published in 1950. It contains all of the features of the previous editions and in addition incorporates helpful suggestions made by competent teachers from many parts of the country. A new section on modern business applications is also included.

The topics covered have been selected from Arithmetic, Algebra, and Geometry in such a manner that there is no "prolonged concentration" on any given topic. The development of concepts is at a slow pace and according to the author a "spiral development" plan is followed. This allows for a return to a given topic to reinforce the learning which has previously taken place and also allows for greater depth each time a topic is re-introduced.

This pattern, as followed, can in a few instances at least cause a certain amount of undesirable discontinuity in the opinion of the reviewer. This would seem to be particularly true in the case of the algebraic concepts introduced. For example, signed numbers and fundamental operations in which they are used are introduced on page 152. Uses of parentheses where the concept seems to be used for the first time is on page 325.

The reviewer also wonders why the introduction of ratio and proportion is delayed until page 376 when these concepts could have been used to advantage in problem solving if they had been introduced much earlier. This is particularly significant since many authorities now advocate the introduction of ratio concept as early as grade five.

Chapter organization is excellent, each chapter being built around a pattern of overview, motivation, presentation, practice, application, games and "something to do," and finally reviews and tests.

A thorough review of fundamental processes with whole numbers, fractions and decimals is a strong feature of the textbook. Many pictures and graphs are used to make the material more interesting and understandable. Effective use of color is employed to emphasize rules and examples. Geometric constructions are widely used and should do much to establish spatial relationships which the student must know to understand the world around him.

A partial listing of the contents of the book would include such topics as circles; whole numbers, angles; common fractions, lines; decimal fractions, triangles; more decimal fractions, percentage, a little algebra, ratio and proportion, graphs, scale drawings, perimeters, volumes, business problems, latitude and longitude. It would seem that this material is timely and should be of interest to the student of general mathematics.

Certain sections are labeled as "Work for the Experts." These are usually short, additional topics placed at frequent intervals to challenge the better student. Most of the algebra and an introduction to statistical methods of finding averages, are included in these sections.

A very fine feature of the book is the appendix in which is included less used or more difficult formulas and topics from mensuration. A picture dictionary of mathematical terms is an unusual and very effective part of this portion of the book.

The book is well written but is very traditional in its presentation of the material covered. Little reference is made to the logical nature of the subject of mathematics and no reference is made to such concepts as the commutative, associative, and distributive laws. Little reference is made to our number system.

Students of general mathematics should find the book interesting and challenging. The book compares very favorably with other books of this type and

perhaps contains a greater variety of material than most other books written for this group of students.

HERBERT HANNON
Western Michigan University
Kalamazoo, Michigan

THE ROMANCE OF CHEMISTRY, by Keith Gordon Irwin, *formerly a teacher of chemistry* at *Colorado State University*. Cloth, xi+148 pages, 15×23 cm. 1959. The Viking Press, Inc., 625 Madison Avenue, New York 22, N. Y. Price $3.75.

This book, which carries the subtitle "From Ancient Alchemy to Nuclear Fission," is a brief but well written outline of the history of chemistry. This history starts with the limited chemical knowledge of the Egyptians and continues through the periods of alchemy, phlogiston chemistry, and modern chemistry down to the time of atomic fission.

It stands to reason that the author of a 140 page treatise can not be too comprehensive in his treatment of chemical history. Many famous chemists have been omitted; absent are the names and the significant contributions of Paracelsus, Liebig, Faraday, Arrhenius, Van't Hoff, E. Fischer, Willard Gibbs and others. Important areas of chemical developments such as the field of electro-chemistry have been omitted. However, the author has taken the main path of the historical development of chemistry and refrained from any side excursions. The continuous thread of chemical progress is followed in an interesting fashion that should hold the attention of the lay reader. I feel that this book should be an excellent chemical history for high school students; it is well within their comprehension. The only previous written book that did the same thing was "Crucibles" by Jaffe. I feel that for high school students Irwin's "Romance of Chemistry," because of its brevity, has an advantage.

The book is well arranged throughout: good paper, good binding, and good illustrations. I feel that it should be on the library shelf of every high school which offers a course in general science or chemistry.

GERALD OSBORN
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Kalamazoo, Michigan

FUNDAMENTALS OF FRESHMAN MATHEMATICS, by C. B. Allendoerfer, *Professor and Executive Officer, Department of Mathematics, University of Washington*, and C. O. Oakley, *Professor and Department Head, Department of Mathematics, Haverford College*. Cloth. Pp. xii+475. 15×23 cm. 1959. McGraw-Hill Book Company, Inc., 330 West 42nd Street, New York 36, N. Y. Price $6.50.

Some four years ago the authors of this text published *Principles of Mathematics* which was one of the first texts which could be called distinctly non-traditional. This book was received with varying degrees of enthusiasm on the part of some teachers while others were distinctly non-enthusiastic. The present book is a general mathematics text which purports to cover traditional topics in a different manner. The authors state it deals with the material usually included under the subjects of college algebra, trigonometry, and analytic geometry, and includes an introduction to calculus. The authors frankly admit there is some overlapping with the previous book that that this is a new book written for a different group of students but with the same general spirit and objective. The authors have had in mind freshman and sophomore pre-engineers and science majors primarily. As contrasted with the earlier book the authors point out that formal logic has been omitted; likewise the theory of groups is omitted, while the treatment of sets is enlarged. A review of intermediate algebra is included; material on probability and statistics is omitted.

There are many excellent features—some of which were especially pleasing to the reviewer. Of these it might be worth mentioning: the exceptionally well selected references for further study of certain topics; the deliberate omission

of stress on logarithms as a means of calculation, in view of the prevalence of calculating machines; the treatment of the angle between two lines in terms of direction cosines rather than slopes (some instructors might wish the formula in terms of slope were at least available); a proof that the graph of a linear equation is a straight line, without the necessity of considering special cases; the inclusion of material on matrices, with determinants as what might be called a sub-topic; the careful attention to rigorous statement of theorems; the emphasis which is placed upon the fact that an expression must have meaning (particularly with reference to expressions involving division by zero).

In some places the text seems very "modern"; at other spots it seems distinctly "traditional"; the material on sets, for example, would have been difficult to find in any elementary text written a score of years ago, yet much of the later material in the text could be studied without every having read the prior discussion of sets. As a secondary school teacher in a refresher course taught by the reviewer once asked: Now that we have this material on sets are we going to use it, and if so, how? It would seem that the authors of the text under consideration are not always going to use some of the new concepts and that by no means is all mathematics as taught a few years ago necessarily obsolete.

Several points, some of which are minor, may bother the instructor planning to use this book. On page 303 it is stated that "in analytic geometry we always assume equal scales on the two axes." There may be an explanation, but the student may feel that this is not true in figures 16.7 and 16.12. No scale is indicated on the axes in some cases, for example figure 15.21. At some spots the student would have been aided in following the discussion if the figure and its treatment could have been on the same page (for example, pages 331–332 or 369–370. It may be that the supply of "word problems" is not adequate. There is one section specifically devoted to this topic involving only twenty problems.

The authors state that this book could be used as a text in advanced twelfth grade secondary school mathematics, in college algebra, in college algebra and trigonometry combined, or in a unified freshman course. Possibly this is an attempt to appeal to a larger market. The text may be usable in a completely unified course but merely adding two or six more chapters does not by any means produce a "unified" course. Some instructors will feel the treatment is too advanced for the average freshman class; others may feel this is true only for certain portions of the text. Be this as it may this is one of the best of what have been termed "modern" texts and must not under any circumstances be omitted from consideration by the instructor seeking a book of this type.

CECIL B. READ
University of Wichita

RADIOACTIVE DEBRIS FROM BOMB TESTS SPREADS RAPIDLY

Radioactive debris from hydrogen bomb tests spreads rapidly in the lower atmosphere, even crossing the equator, scientists at the Naval Research Laboratory have found.

They charted the distribution of a new tracer, radioactive tungsten produced in the 1958 Hardtack series of nuclear tests, at 18 stations located principally along the 80th meridian, from Coral Harbour, Northwest Territories, Canada, to Punta Arenas, Chile. Other fission products, such as strontium-90, were also collected and their distribution analyzed.

The NRL scientists reported that their survey showed for the first time that an "appreciable quantity of radioactive matter from a known source in the Northern Hemisphere has been identified south of the equator."

Thus, radioactive debris introduced into the lower atmosphere at a particular latitude does not remain in any restricted zone near that latitude, as had been thought, but spreads rapidly throughout the hemisphere.

"If such materials are introduced simultaneously on both sides of the equator, as happened in this case, rapid spread throughout both hemispheres occurs," the scientists concluded. Their report on contamination of the air by radioactivity from 1958 nuclear tests at the U. S. Pacific Proving Ground in the Eniwetok-Bikini area appears in *Science*.

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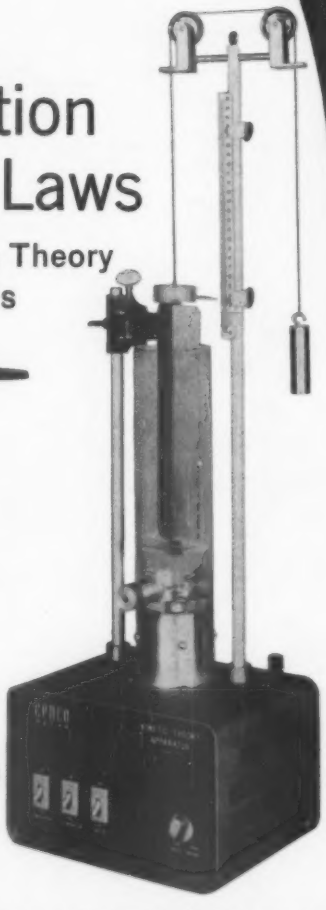

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